

Mars Exploration Rovers: 4 Years on Mars

Geoffrey A. Landis

This January, the Mars Exploration Rovers "Spirit" and "Opportunity" are starting their fifth year of exploring the surface of Mars, well over ten times their nominal 90-day design lifetime. This lecture discusses the Mars Exploration Rovers, presents the current mission status for the extended mission, some of the most results from the mission and how it is affecting our current view of Mars, and briefly presents the plans for the coming NASA missions to the surface of Mars and concepts for exploration with robots and humans into the next decade, and beyond.

Four Years on Mars: ***the Mars Exploration Rovers***



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Presentation at MIT Department of Aeronautics and Astronautics, January 18, 2008

Exploration - Landis

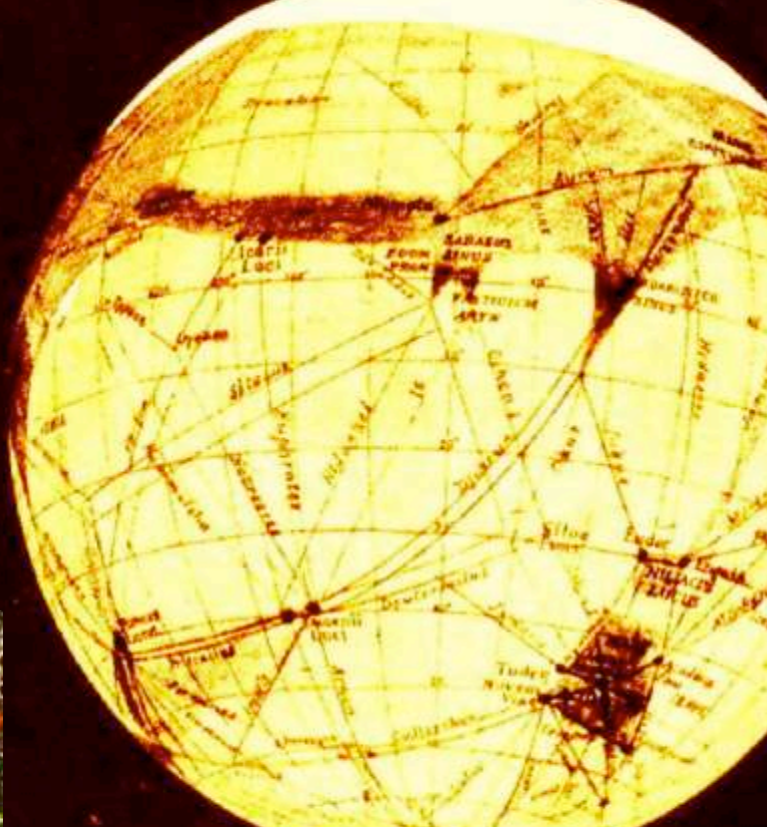


Mars viewed from the Hubble Space Telescope

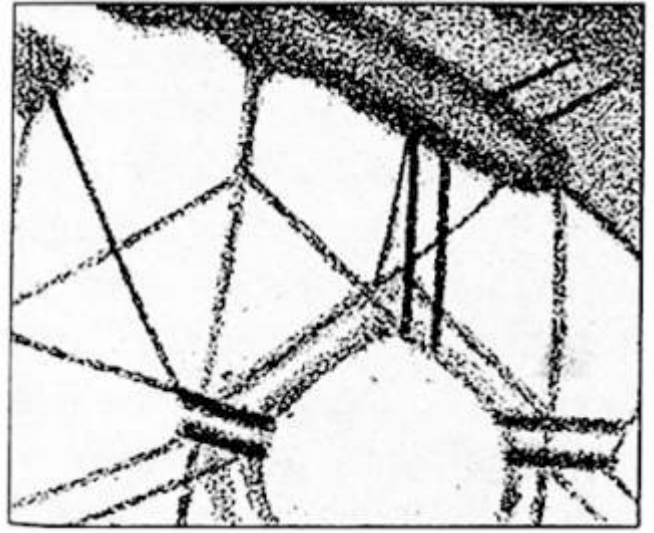
Exploration - Landis

Views of Mars in the early 20th century

Lowell 1908



A circular celestial map from 1908, likely a reproduction of a historical astronomical chart. The map is yellowed and features a grid of lines. Numerous stars are labeled with names like 'Aldebaran', 'Betelgeuse', and 'Rigel'. A small inset in the bottom left corner shows a portion of a spacecraft or satellite.



Sciaparelli 1888



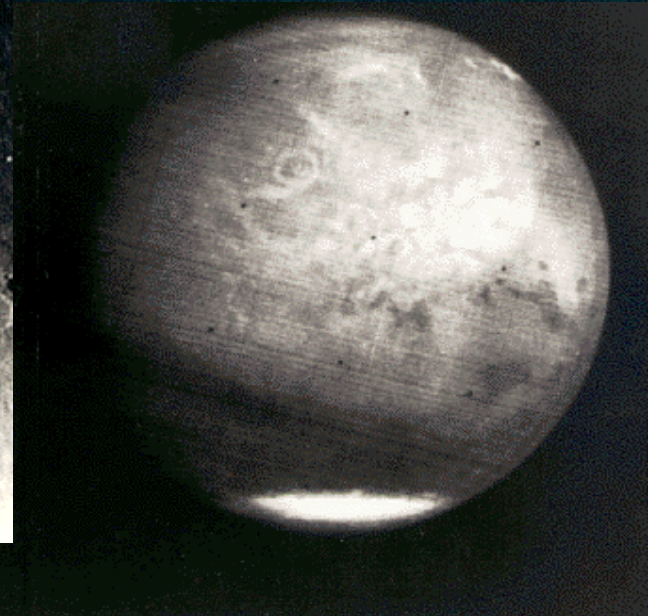
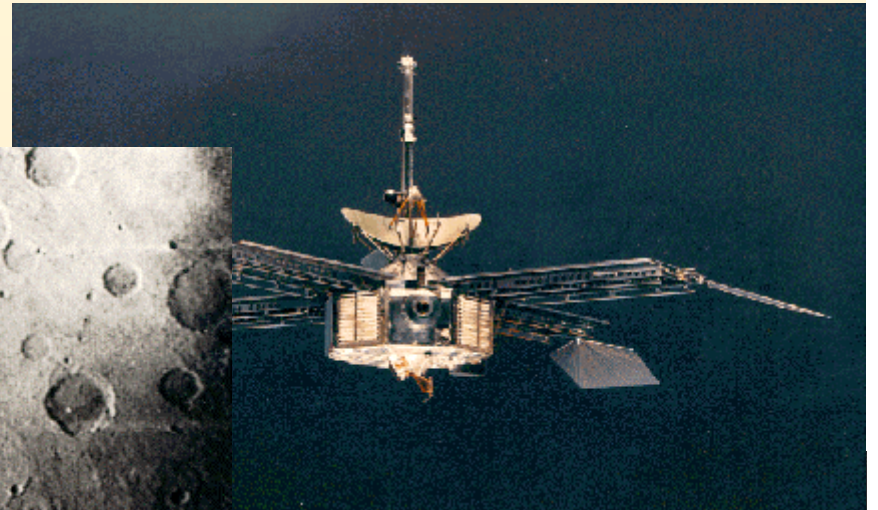
Tales of Outer Space ed. Donald A. Wollheim, Ace D-73, 1954
(From Winchell Chung's web page projectrho.com)



Burroughs 1912
(cover painting by Frazetta)

Exploration - Landis

Past Missions to Mars:
*first close up images of Mars
from Mariner 4*



Mariner 4 discovered Mars
was a barren, moon-like desert

Viking 1976

Signs of past water on Mars?



Photo from orbit by the
1976 Viking orbiter

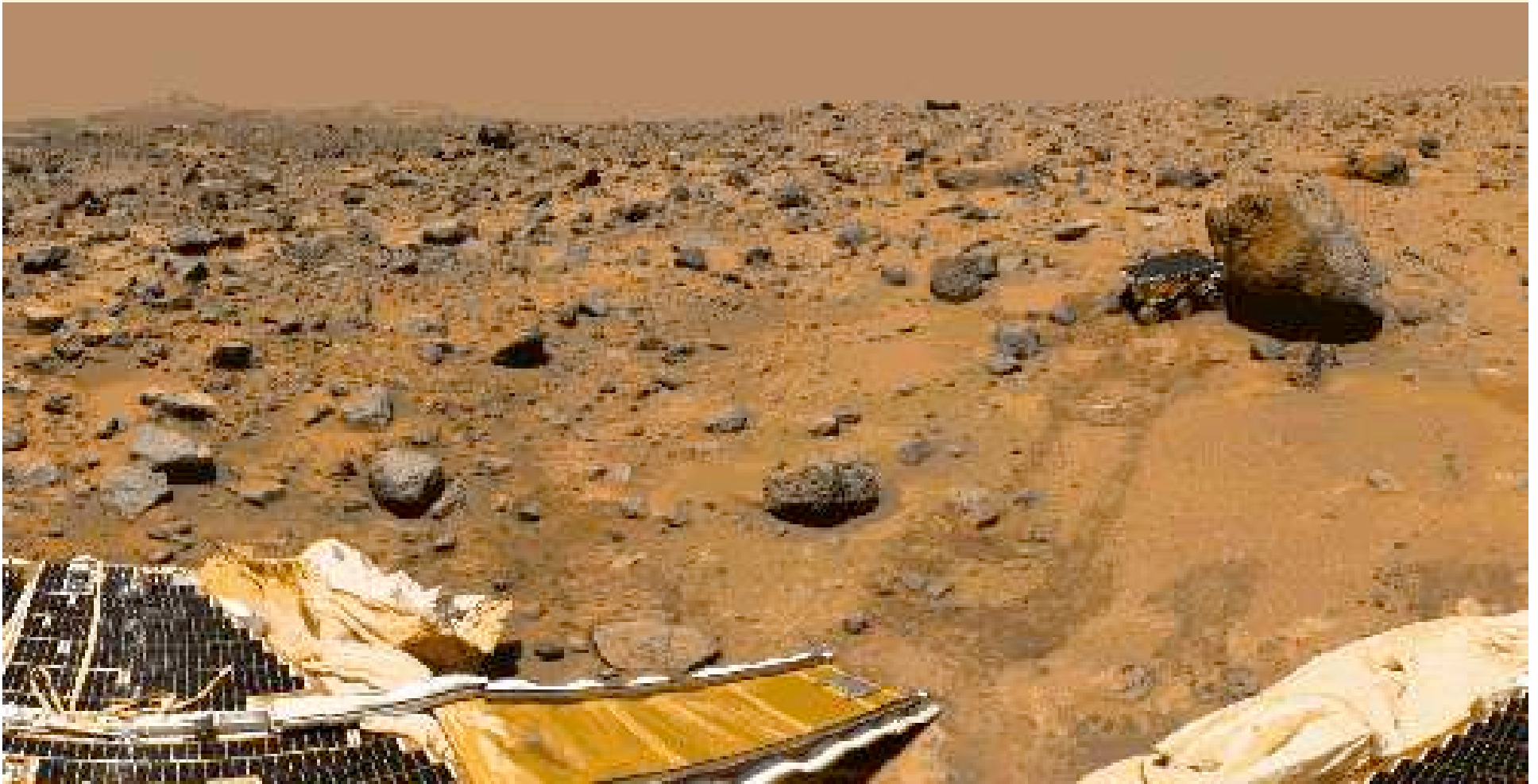
Pathfinder and Sojourner
Rover:
**a solar-powered
mission to Mars**
July 1996

The Sojourner rover was about
the size of a Cocker Spaniel

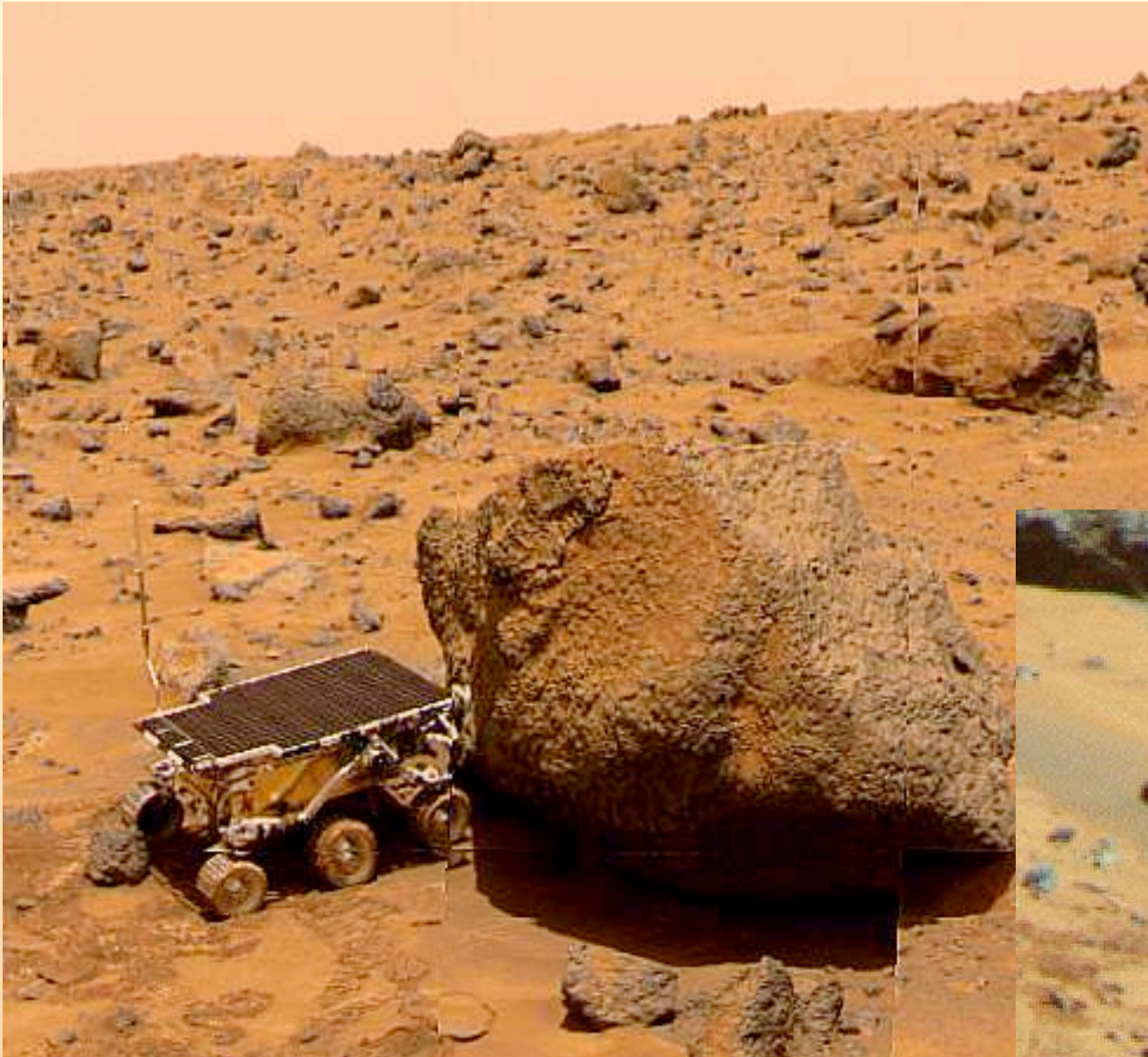
Geoff Landis poses with the
Sojourner rover

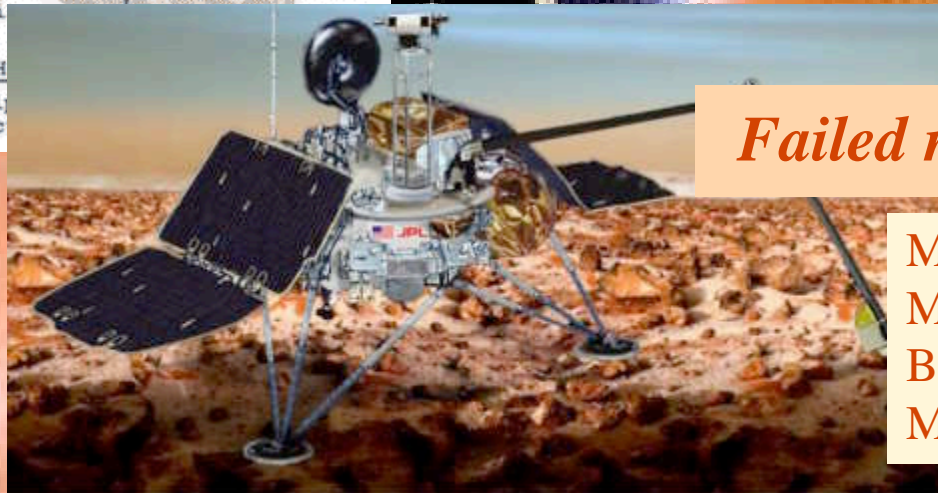
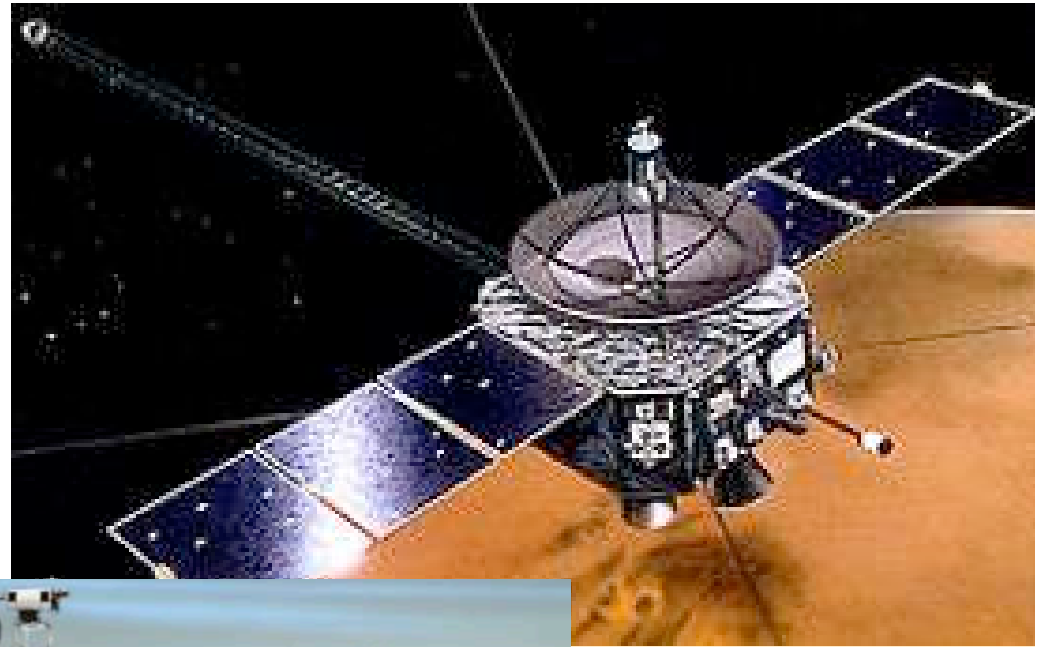
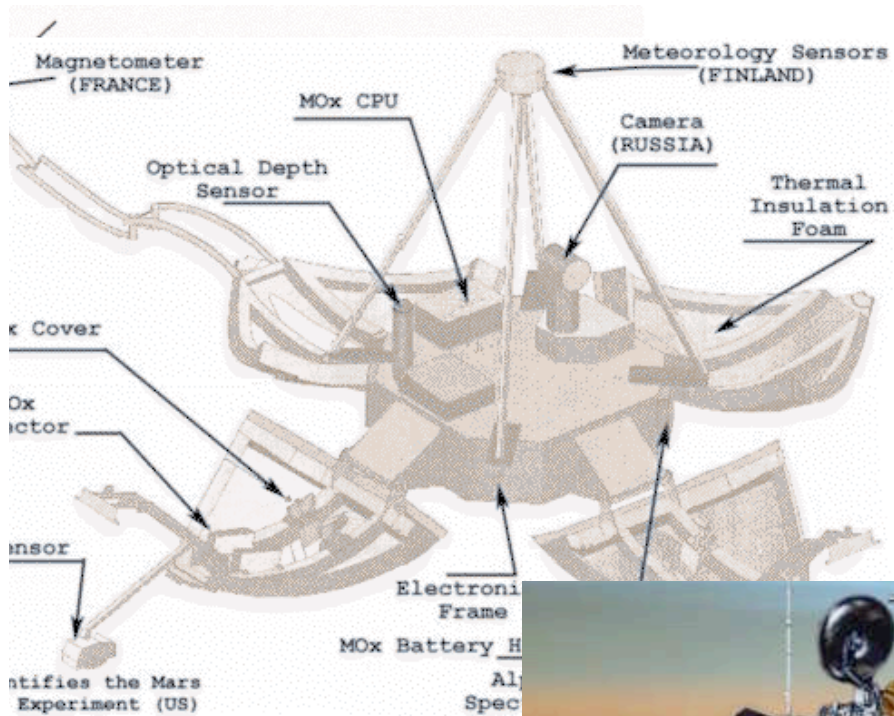


Sojourner: down the ramp and exploring Mars



Sojourner on Mars!





Failed missions to Mars

Mars Climate orbiter
Mars 96, Nozomi,
Beagle-2,
Mars Polar Lander

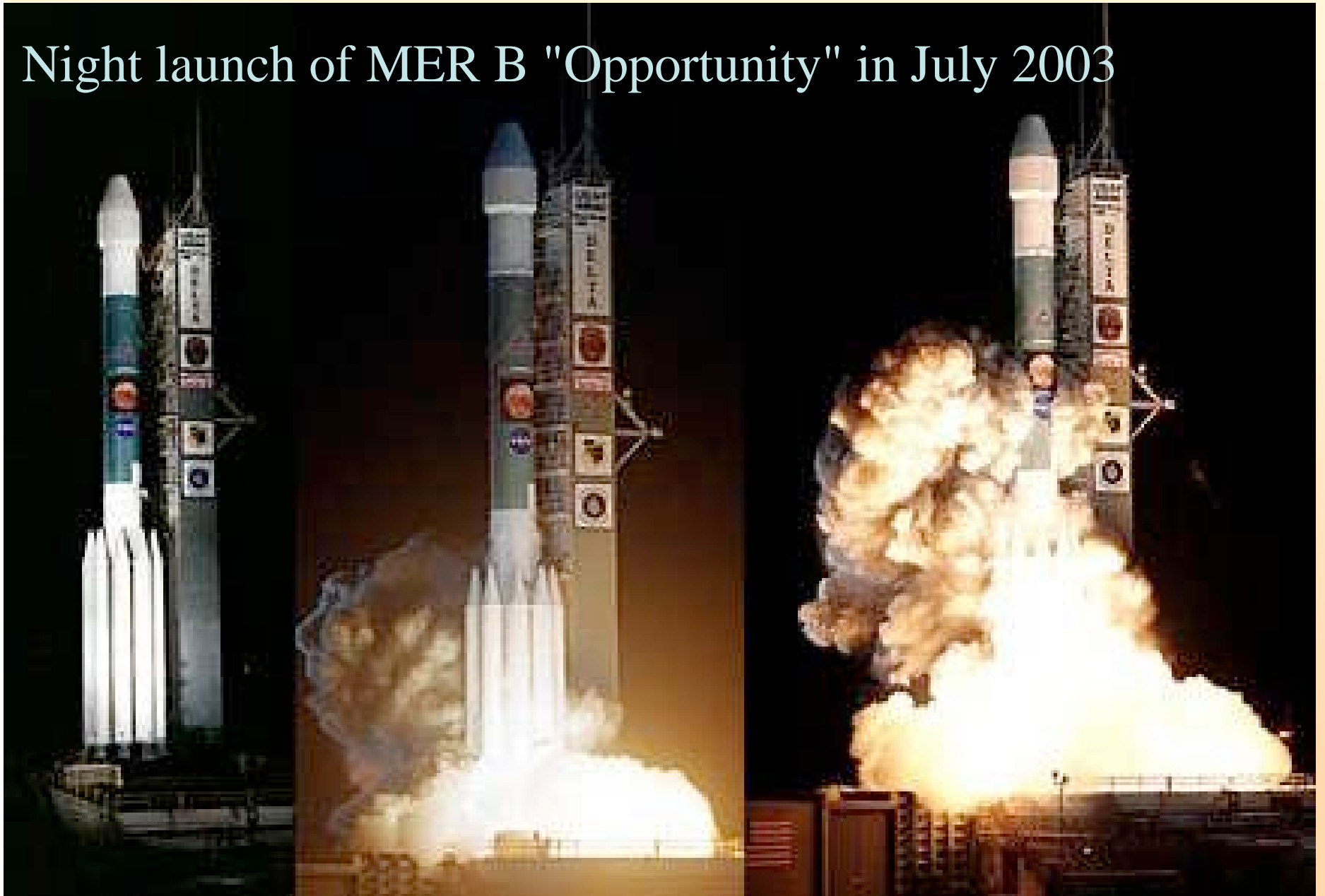




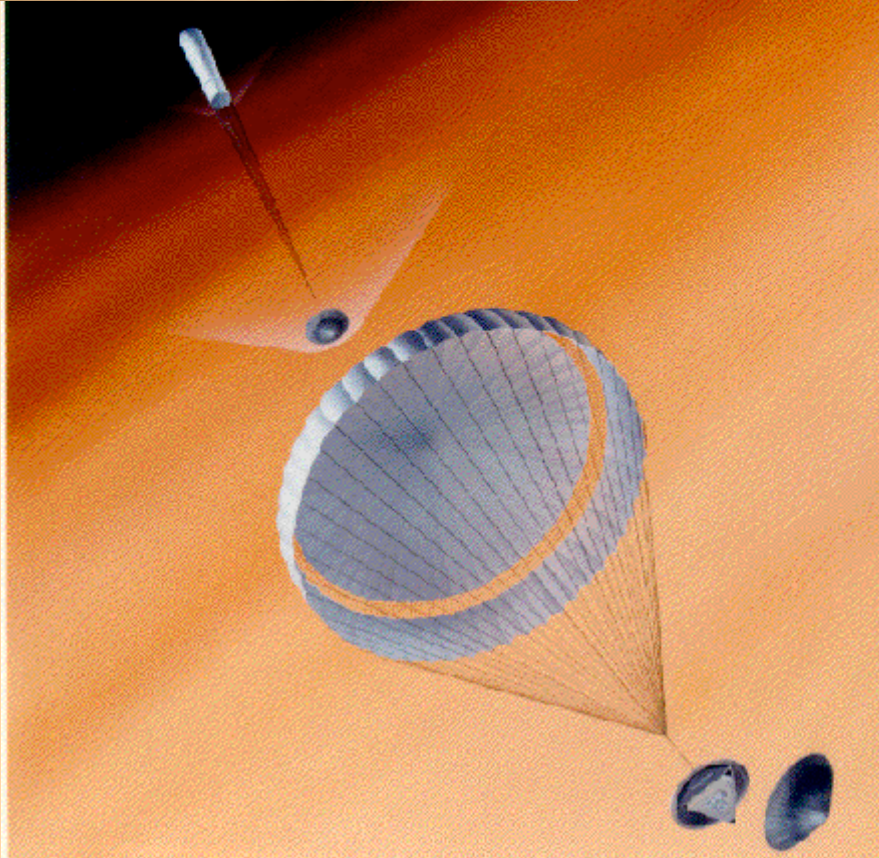
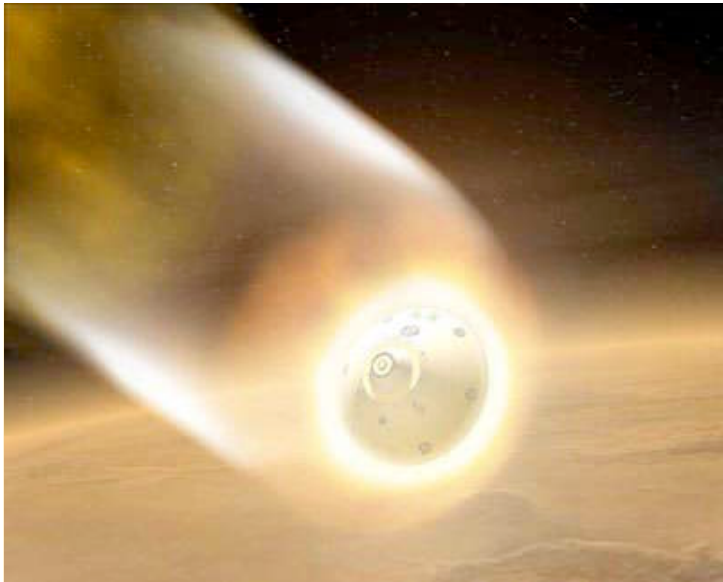
Spirit launch

Exploration - Landis

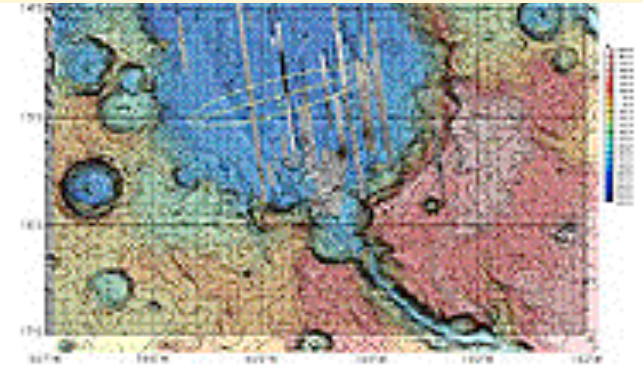
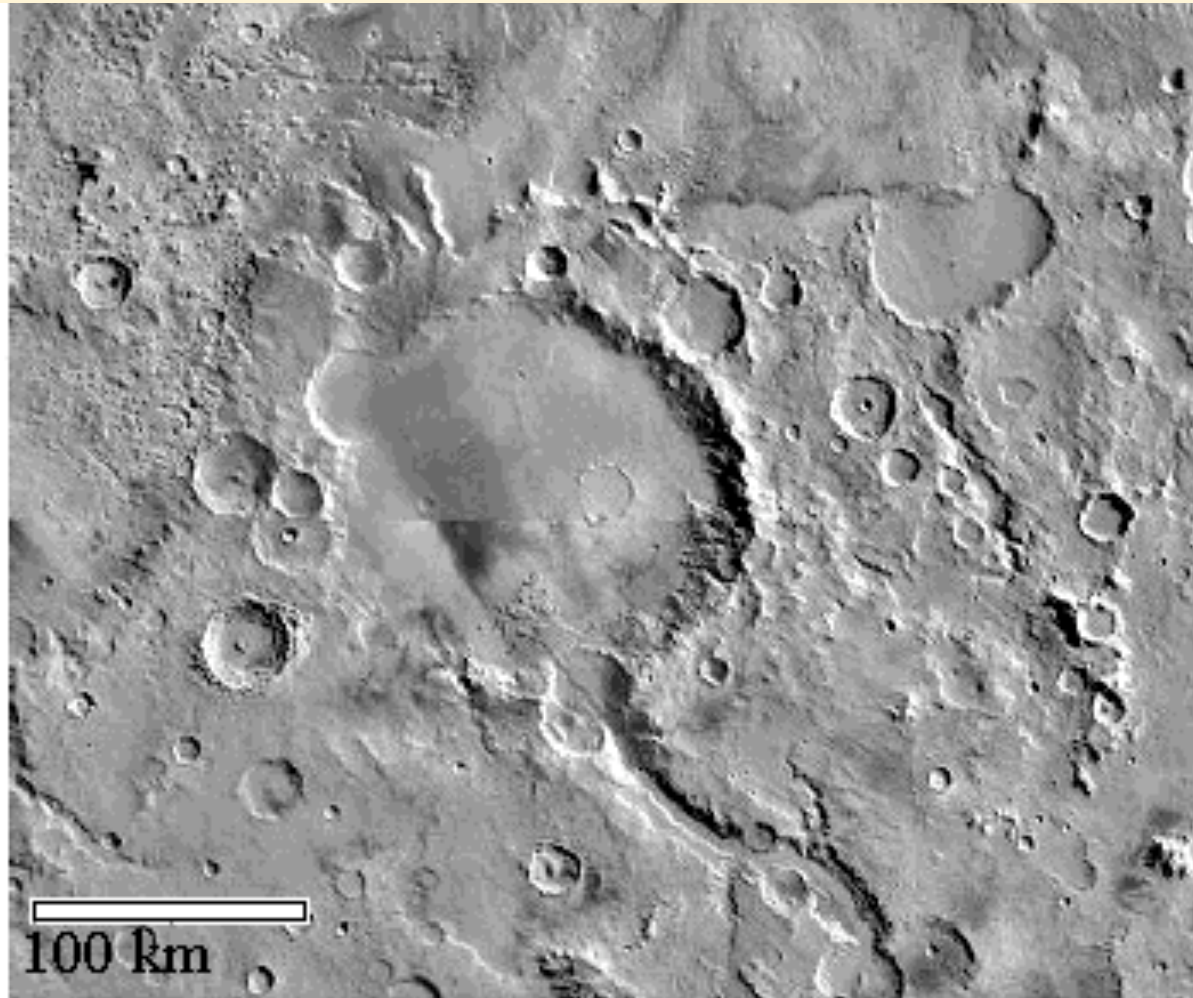
Night launch of MER B "Opportunity" in July 2003



"bouncedown"
airbag landing on Mars



Spirit landing site



Gusev Crater
landing site: a
Martian dry lake
bed

left: Viking orbiter image

The NASA Mars exploration strategy:
“Follow the water!”

Gusev crater landing site



First view of the site after the landing: rocks, sand, and mountains

Opportunity Rover landing



Landing trajectory with bounces:
hole in one!

Eagle Crater

Lander

Opportunity in
Eagle crater
(viewed from
orbit)!

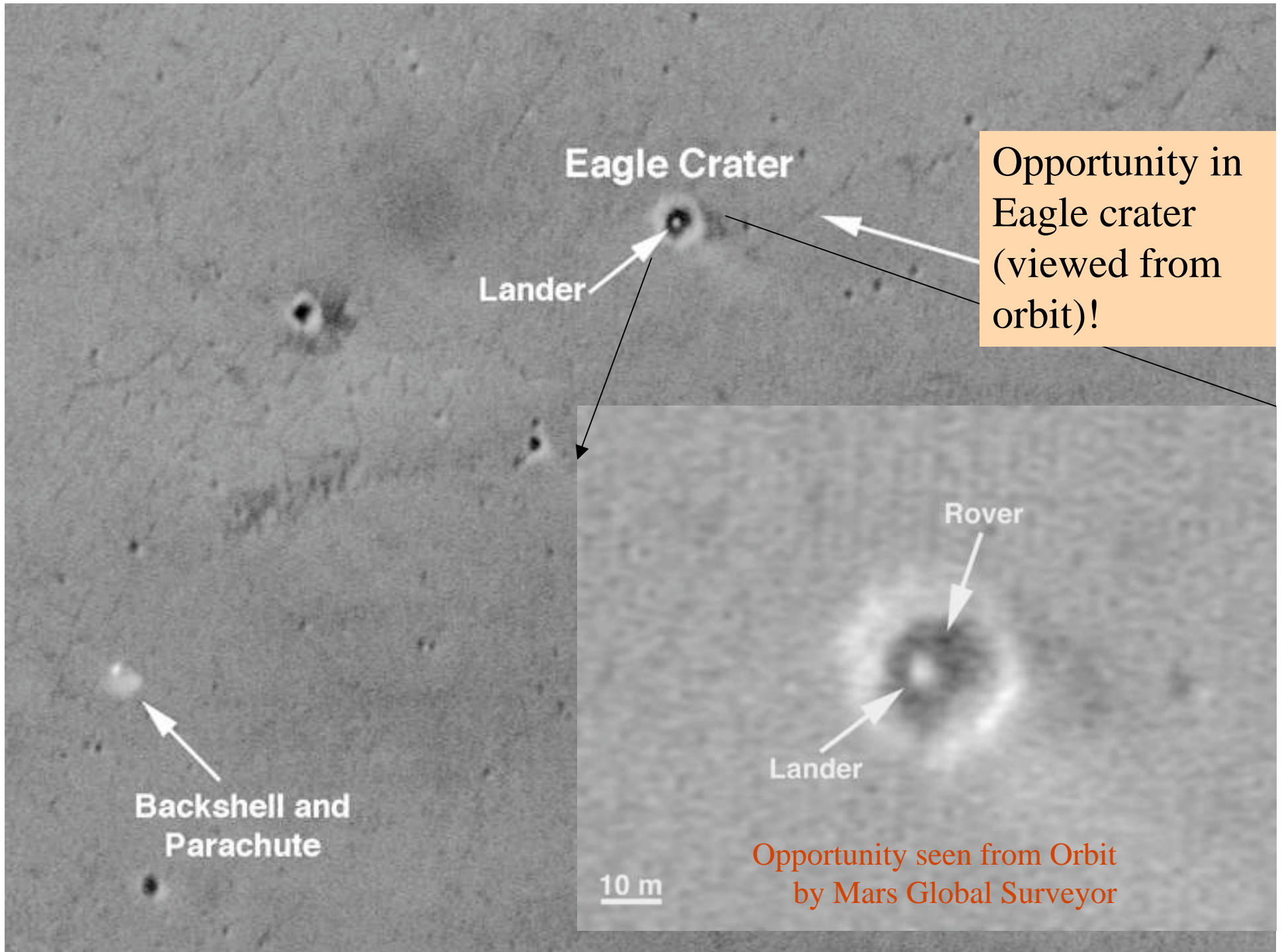
Backshell and
Parachute

Rover

Lander

10 m

Opportunity seen from Orbit
by Mars Global Surveyor



Eagle Crater--View from Opportunity

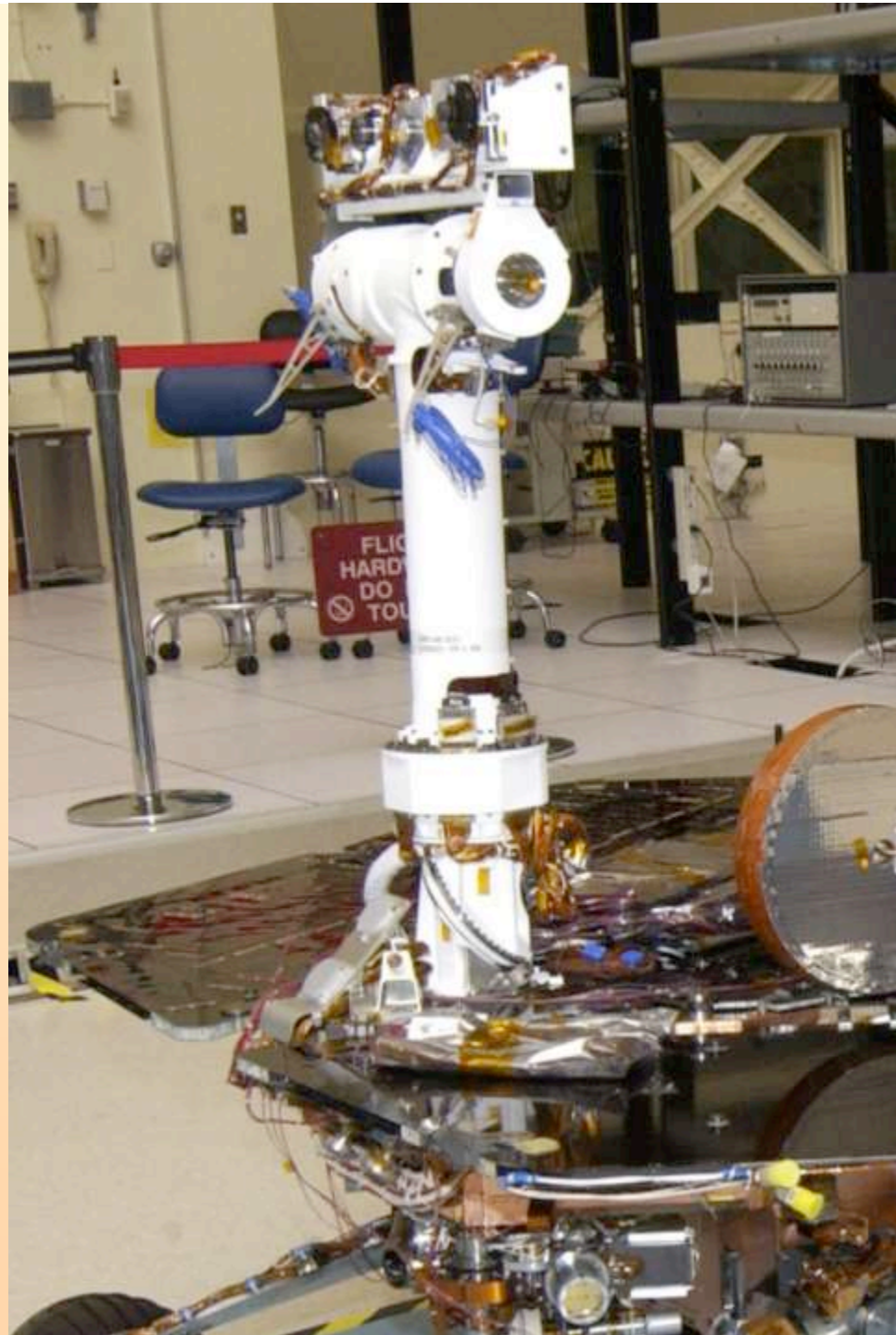


Opportunity Outcrop "El Capitan"



Note: Colors are stretched

Pancam mast assembly



True color: what your eye would see



Mars is primarily adobe-orange in color. The geologists usually enhance the color contrast so that subtle differences in color of different minerals can be seen

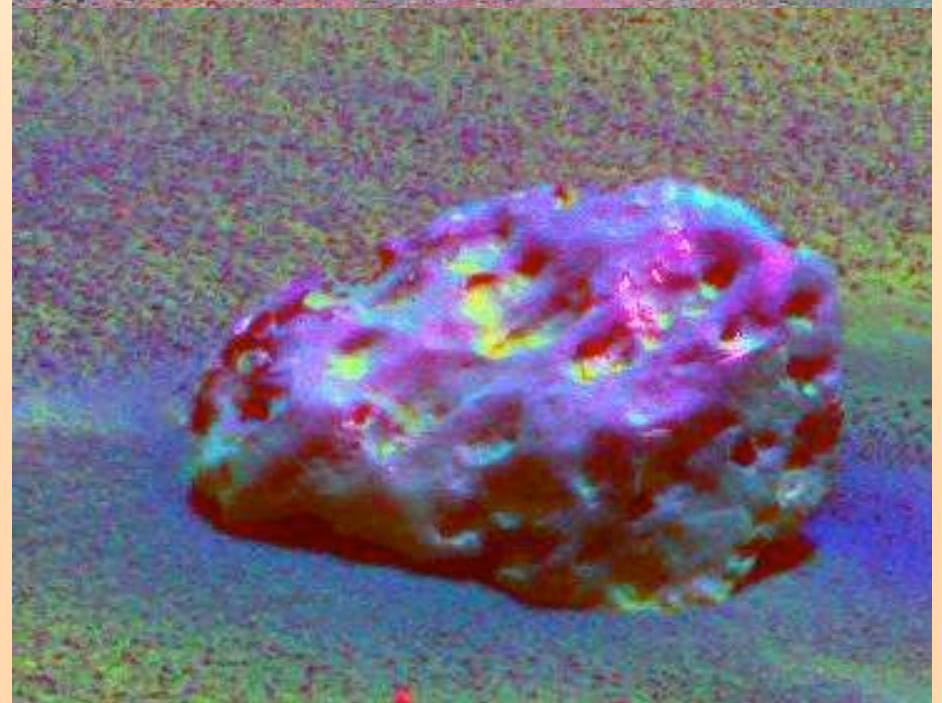
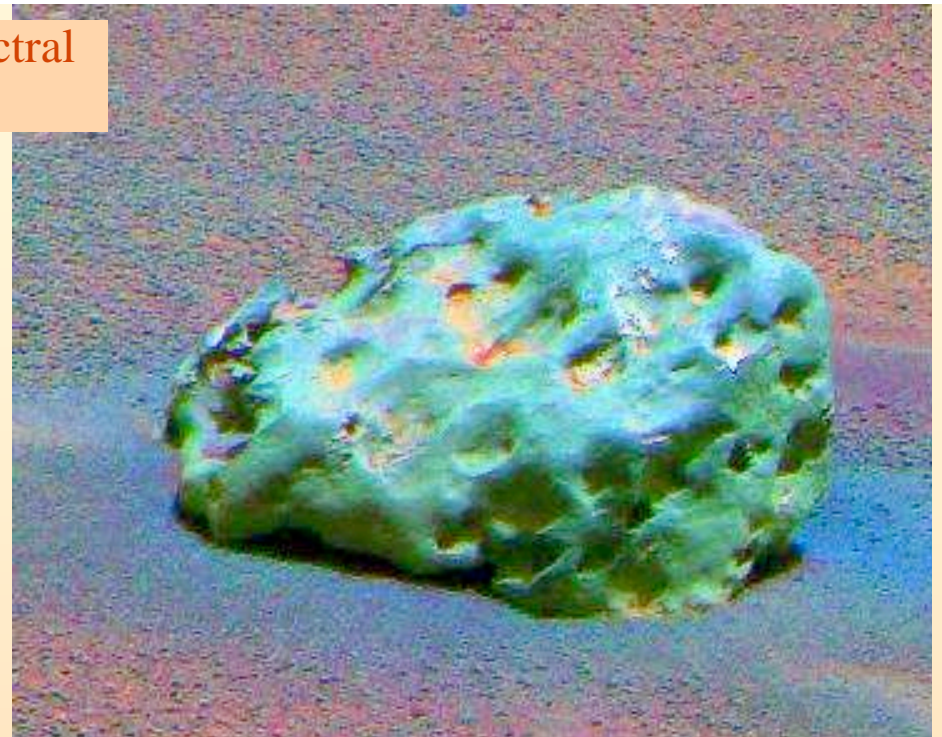
Color of Mars

Stretched color:
enhanced to bring out mineralogy

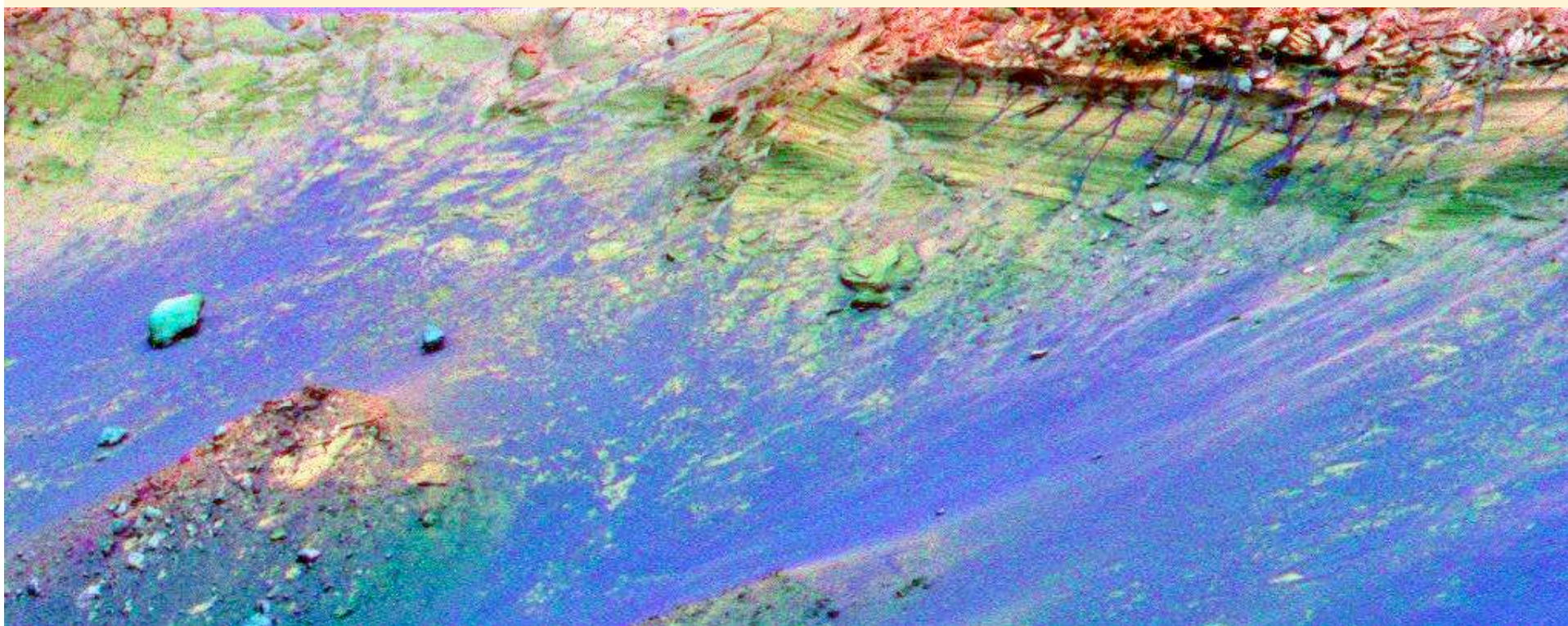


Exploration - Landis

Pancam "Decorrelation" stretch: different spectral contrast bring out different features



Pancam R126 decorrelation stretch Endurance



(courtesy Bill Farrand, Sol 271)

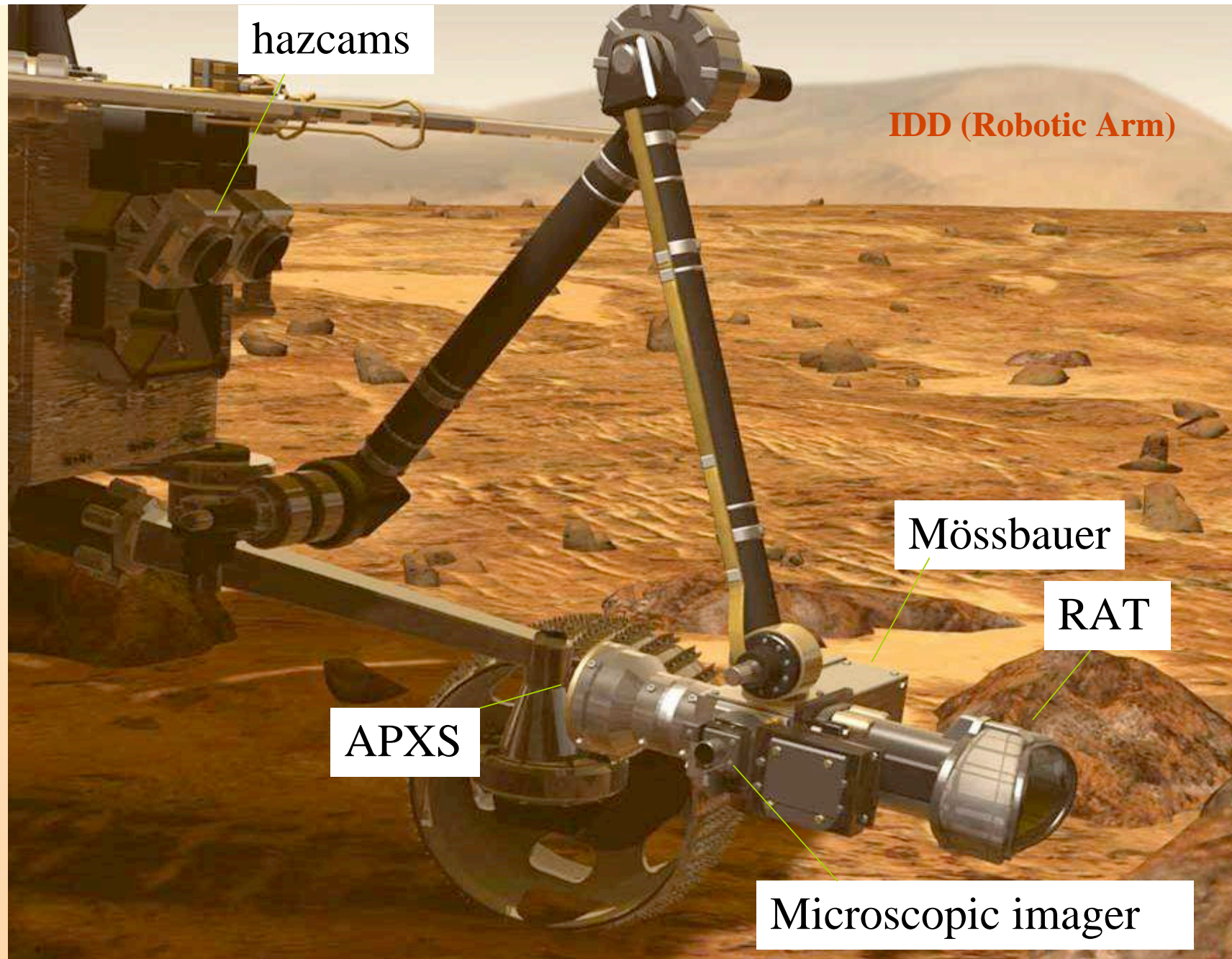
R126 = "blue, red, infrared"

R1 - 430 nm

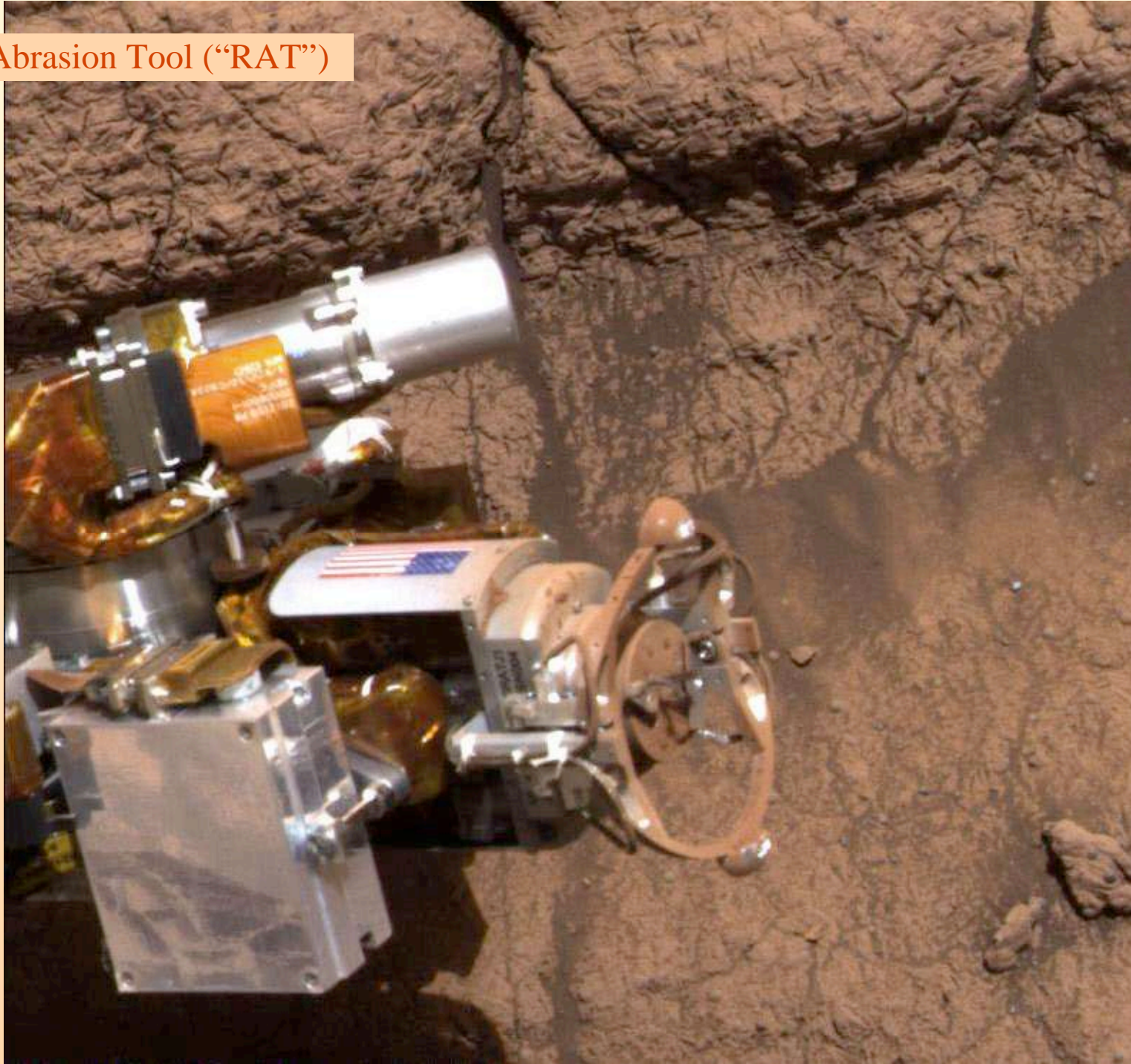
R2 - 750 nm

R6 - 930 nm

Exploration - Landis

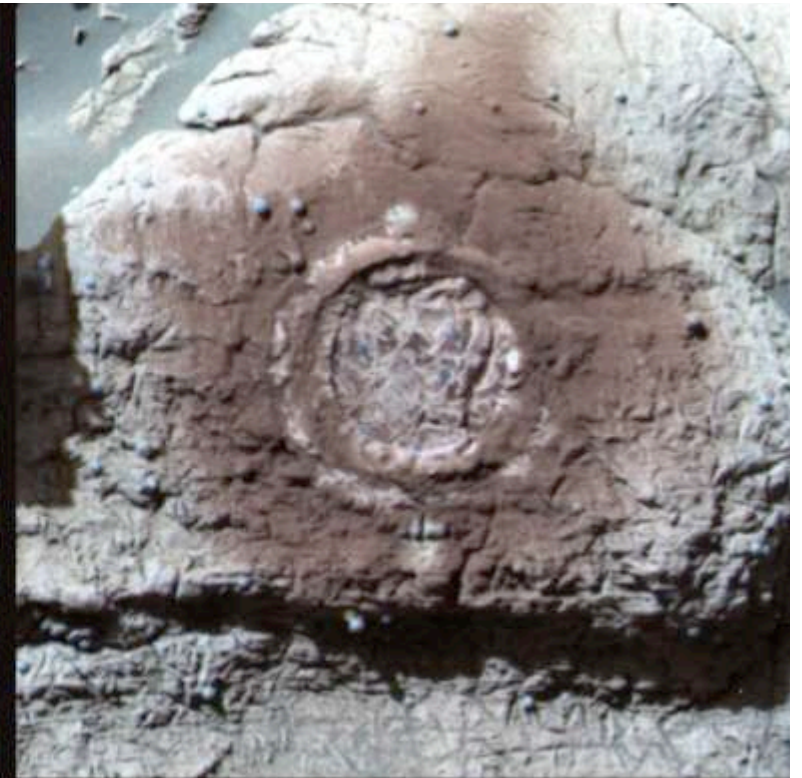


Rock Abrasion Tool (“RAT”)

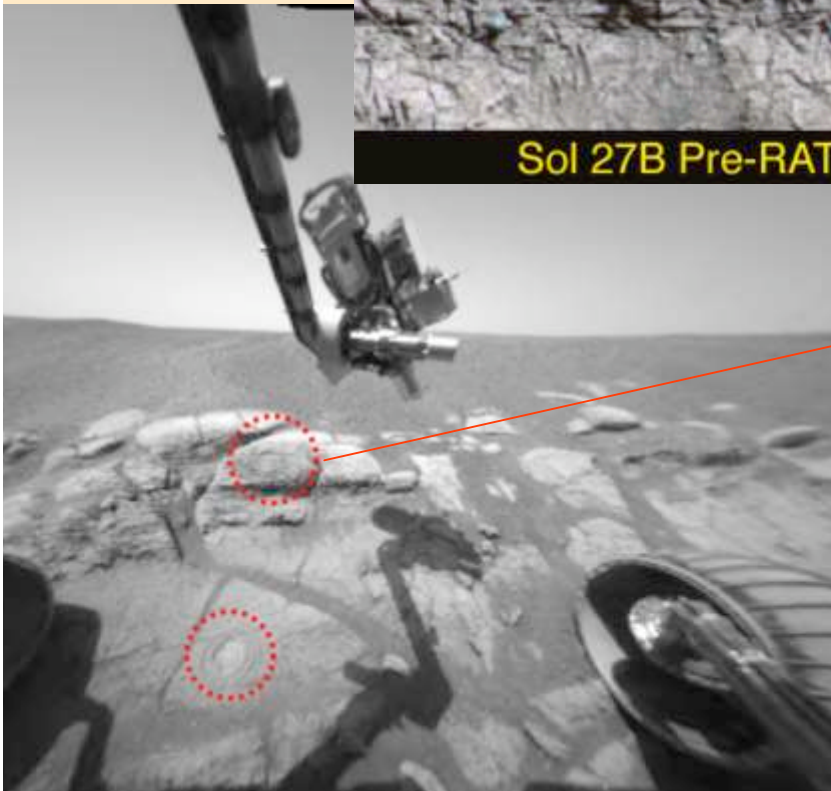




Sol 27B Pre-RAT, Hole 2



Sol 35B Post-RAT, Hole 2



RAT hole
(before and after grinding)

IDD

Tools on the IDD
“robotic arm”
(view looking down
on the robotic arm in
front of the rover)

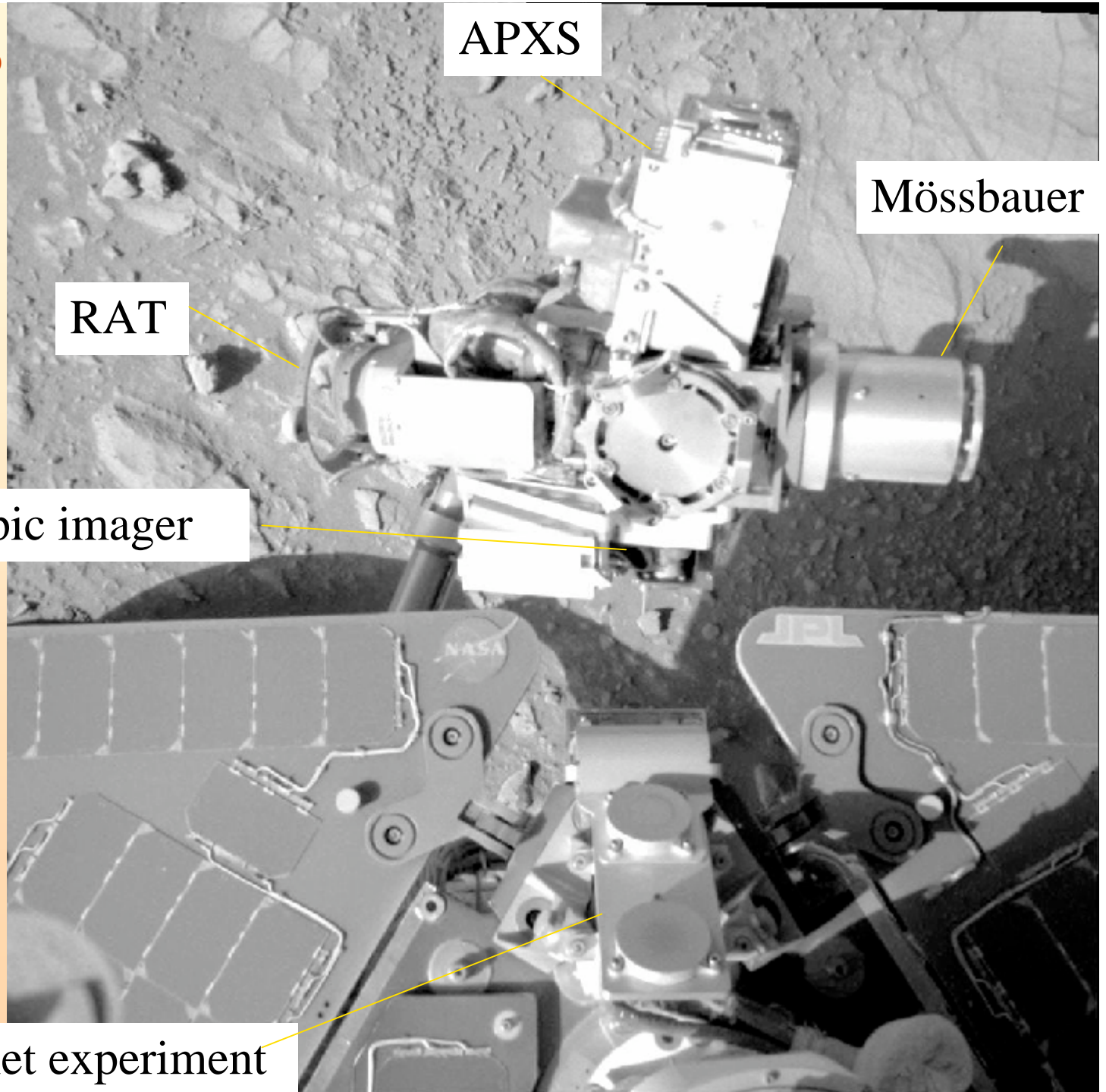
APXS

Mössbauer

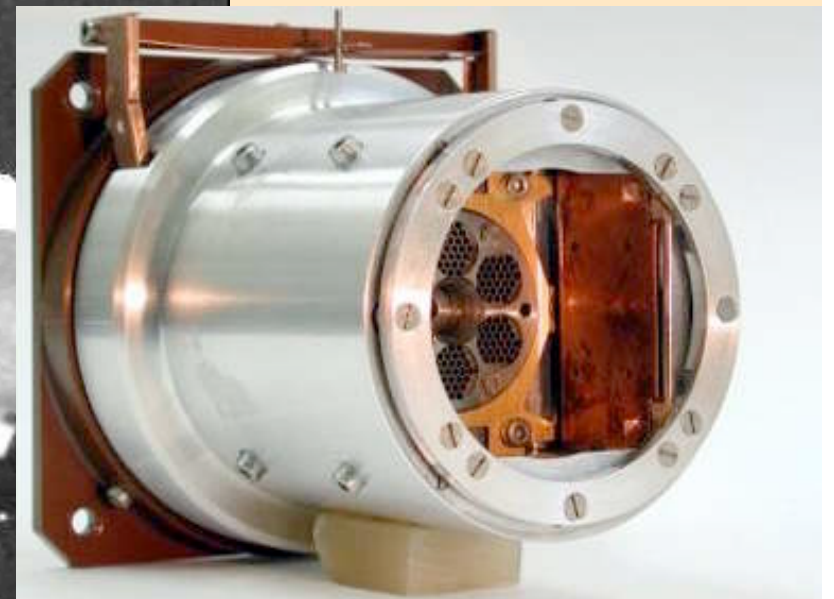
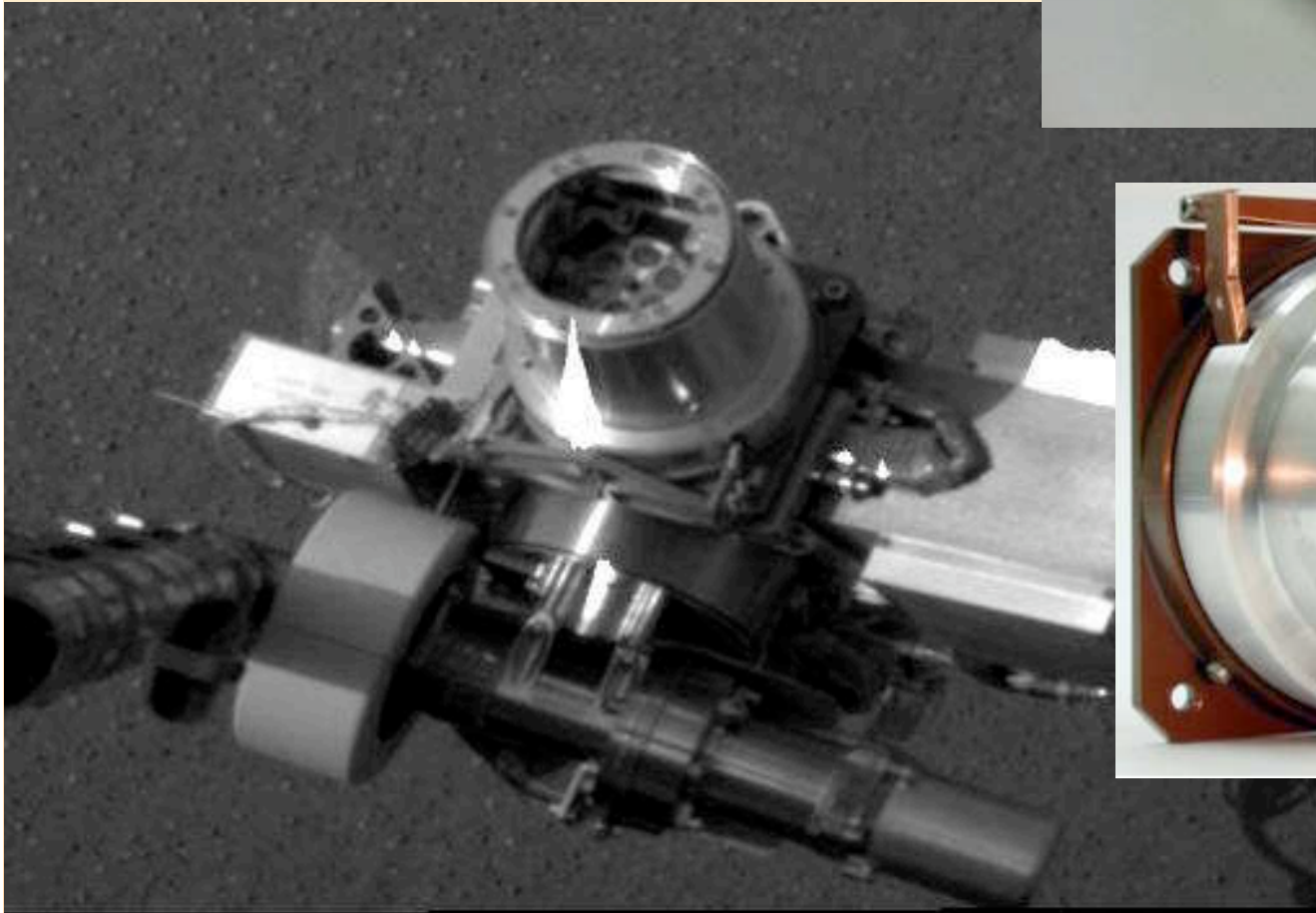
RAT

Microscopic imager

Magnet experiment

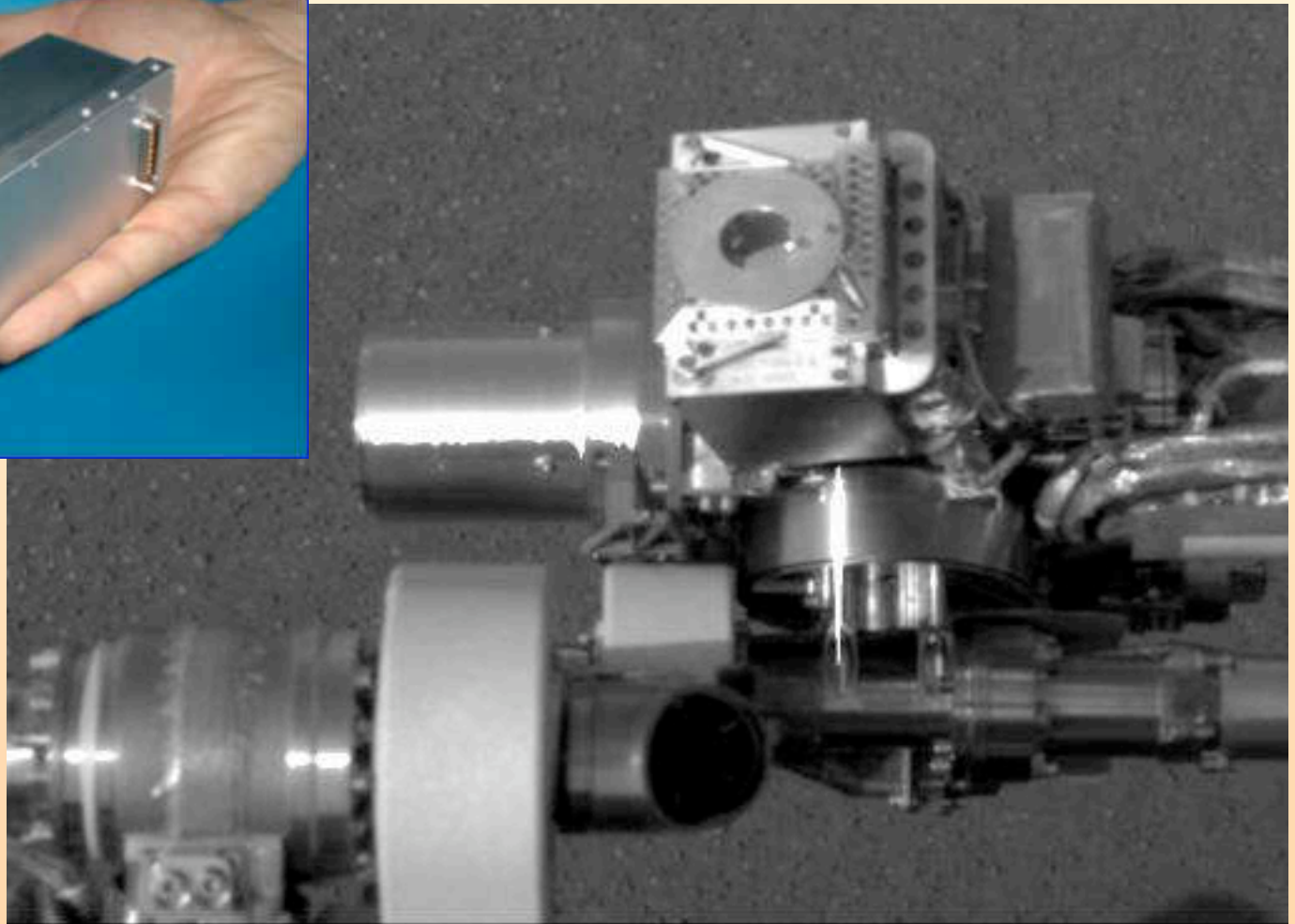
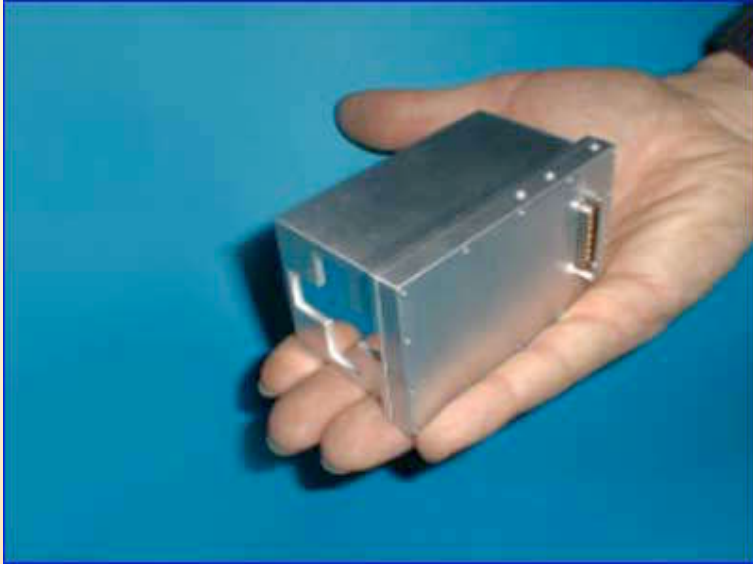


APXS

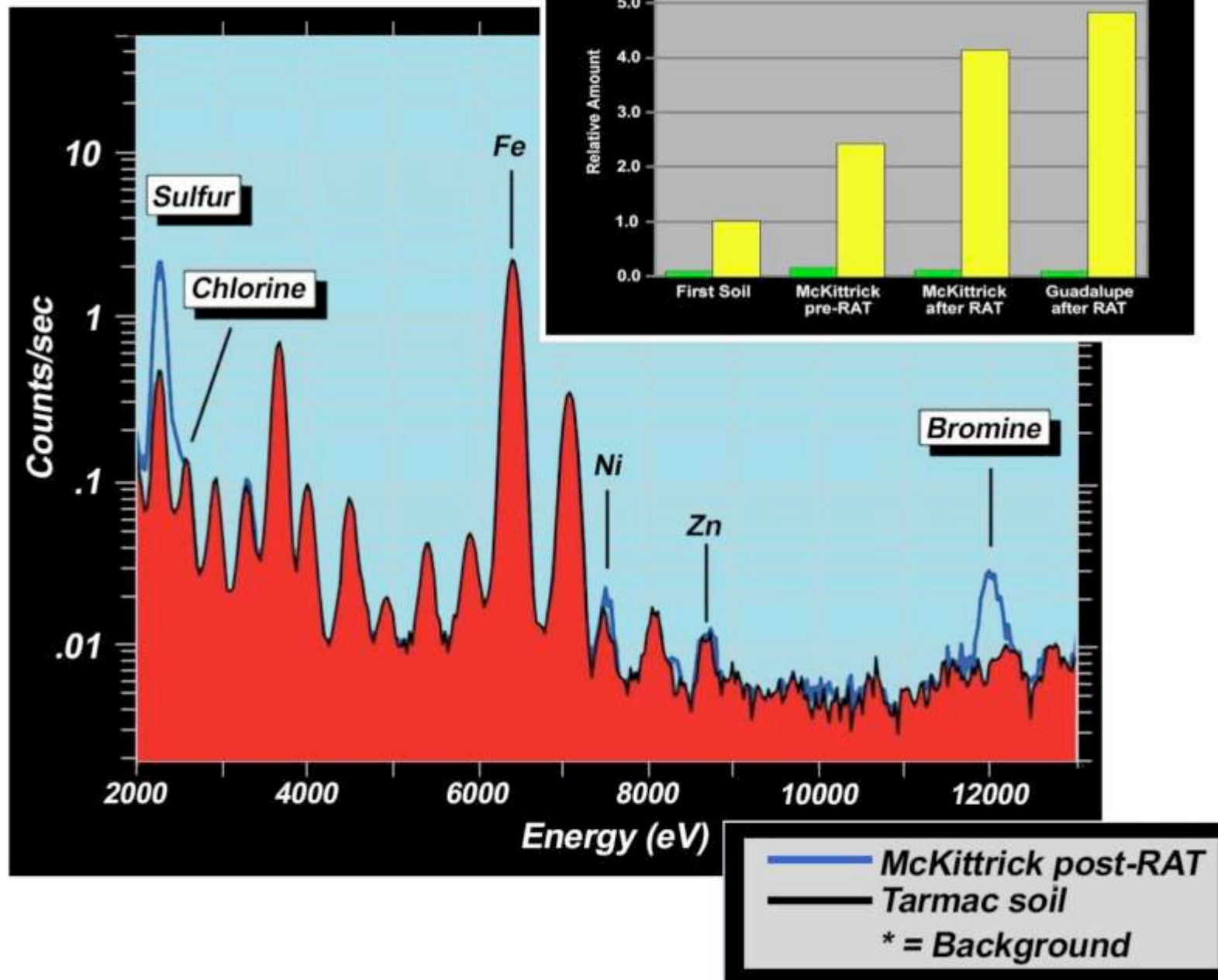


Exploration - Landis

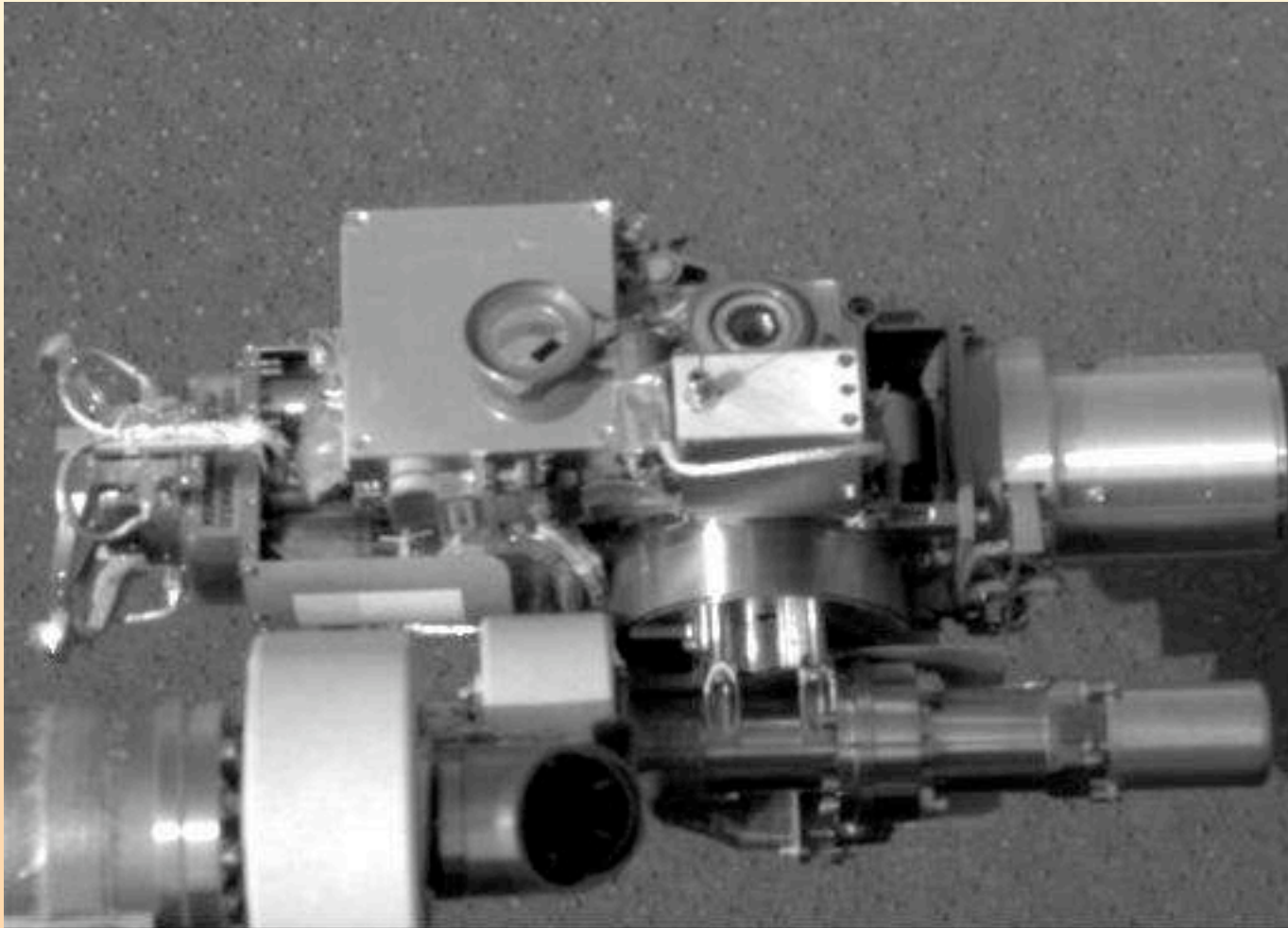
Mössbauer spectrometer



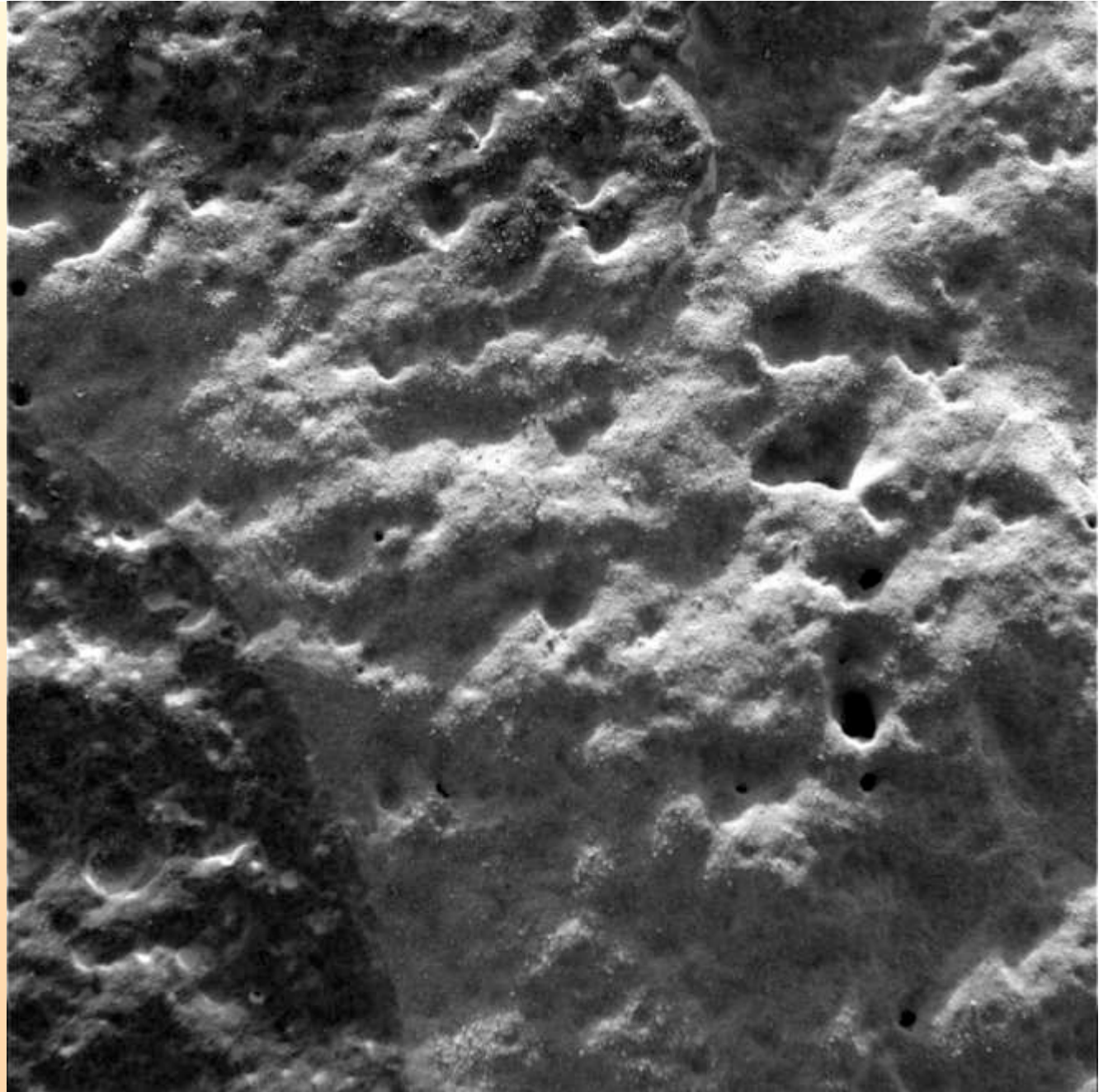
Example APXS results (Opportunity)



Microscopic imager on Mars



Picture from Microscopic
Imager (MI)



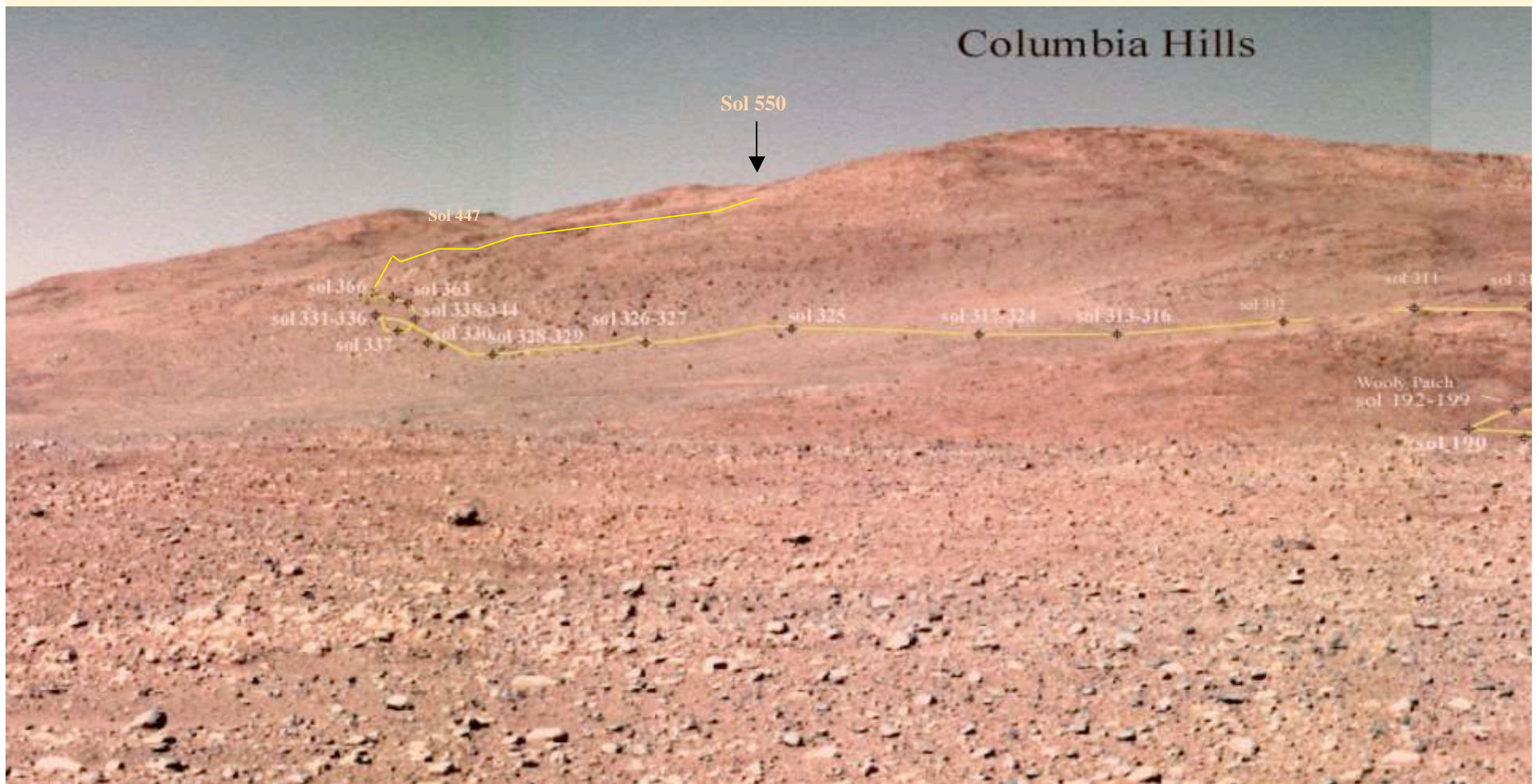
Distant hills....



Spirit: Heading for the hills
(800 meters)



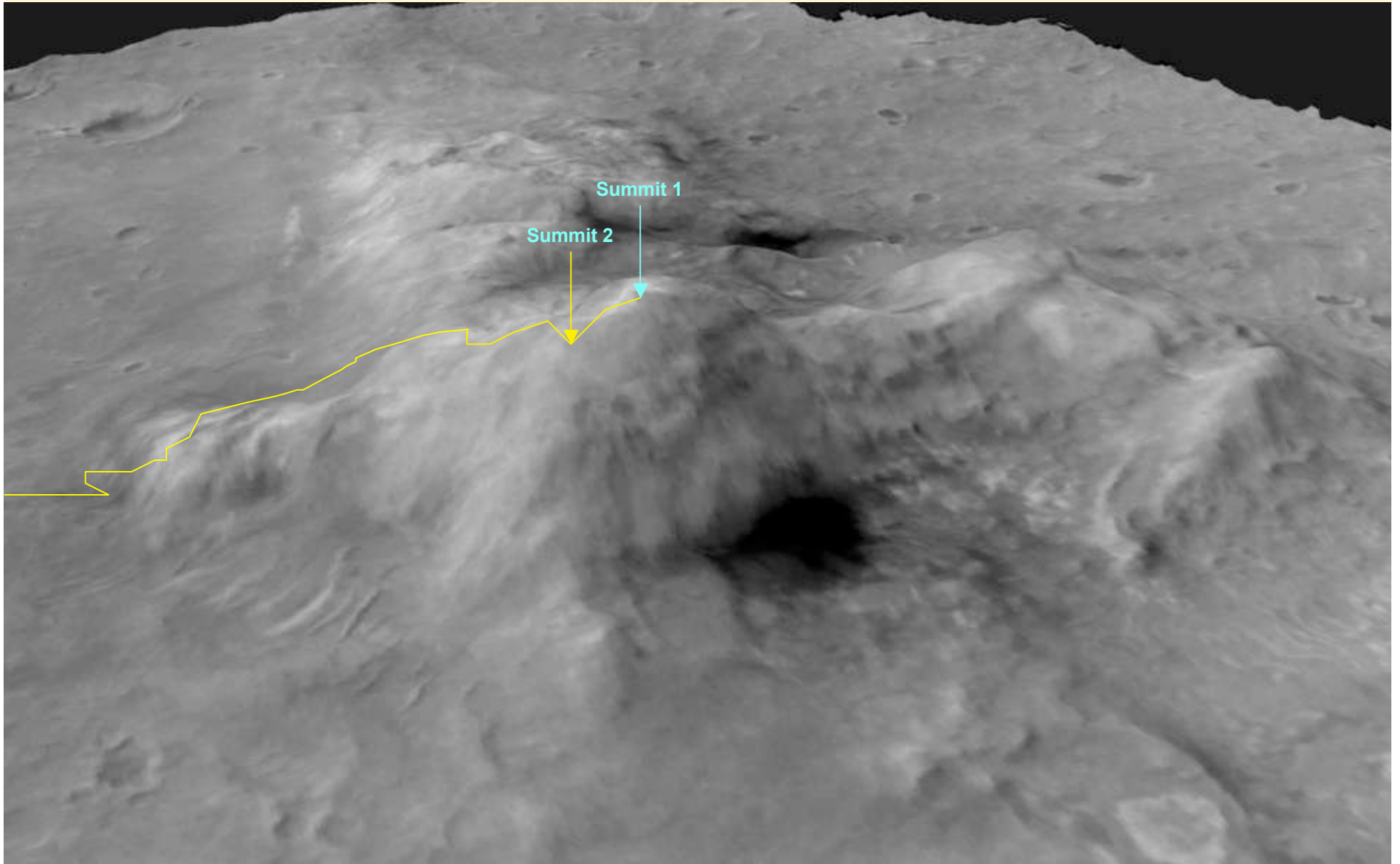
Climbing the hills



(Color is stretched)

Exploration - Landis

Spirit: Climbing Columbia Hills



On the summit

Exploration - Landis

Opportunity's tracks, seen from orbit

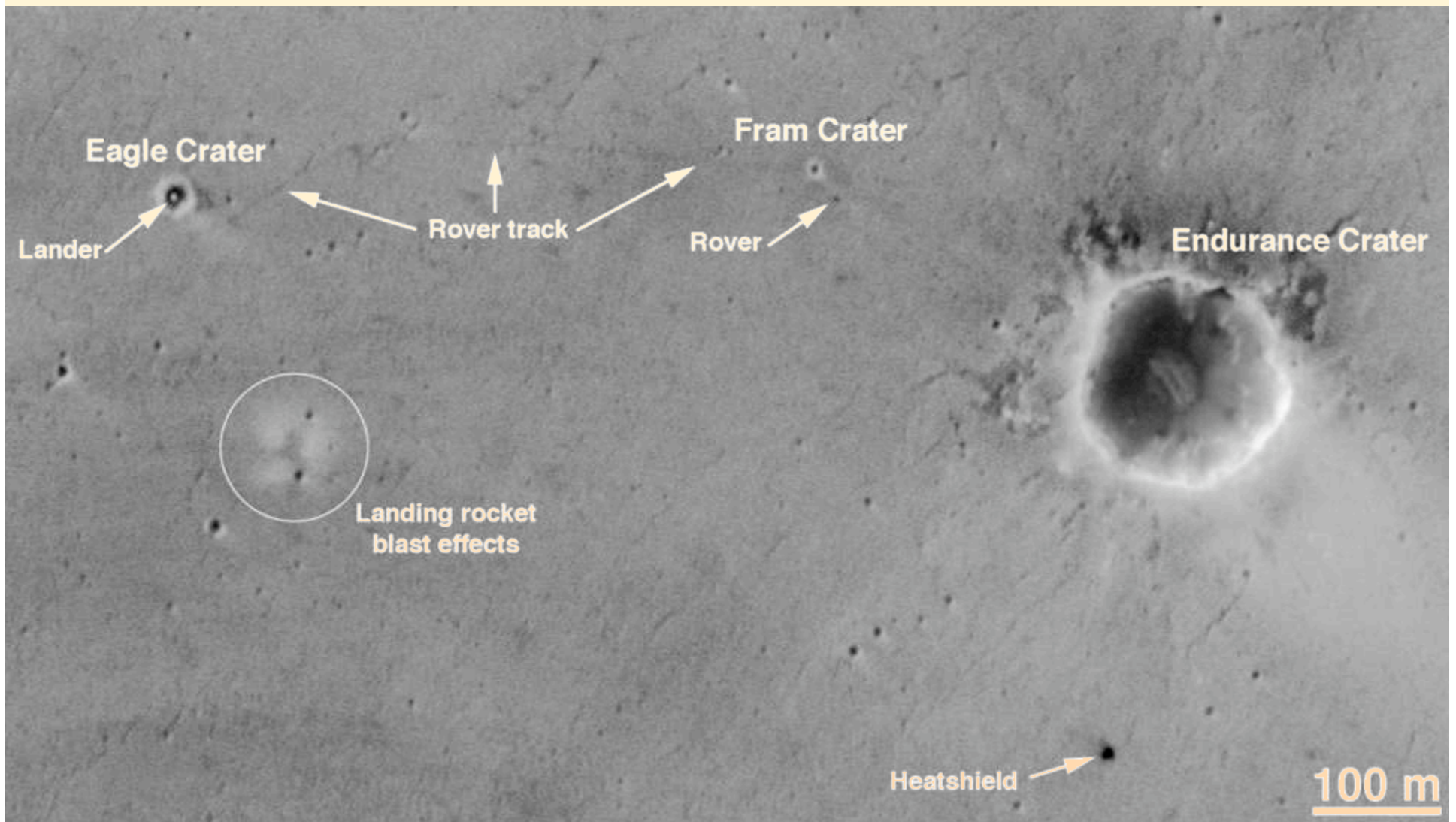


Image from Mars Global Surveyor
courtesy Malin Space Sciences

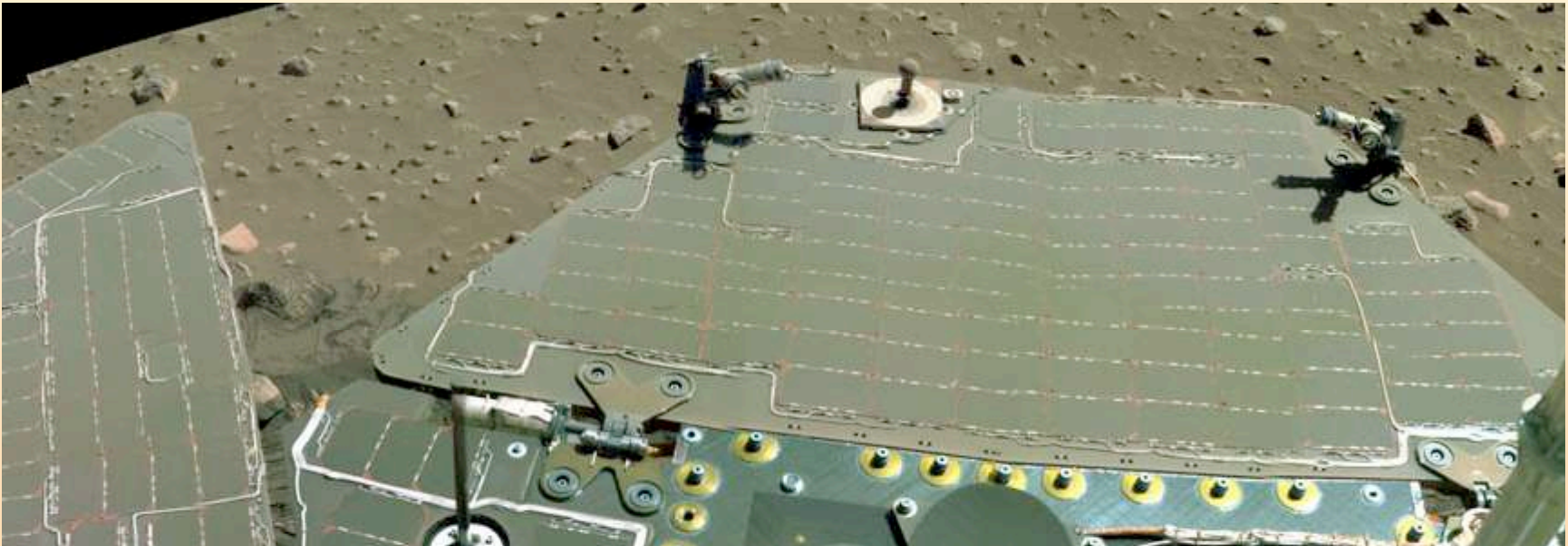
"Endurance" crater





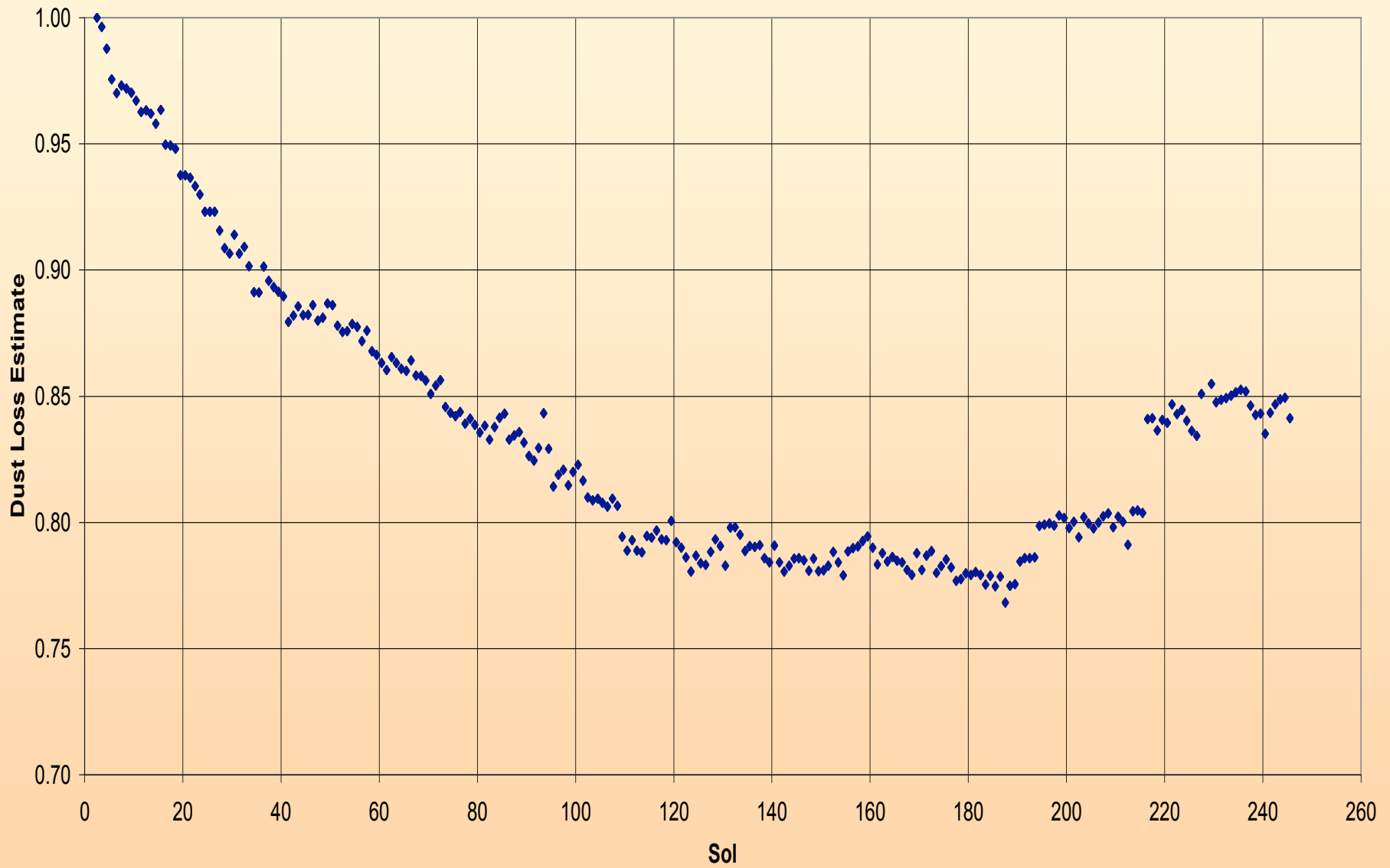


Spirit array: getting dusty



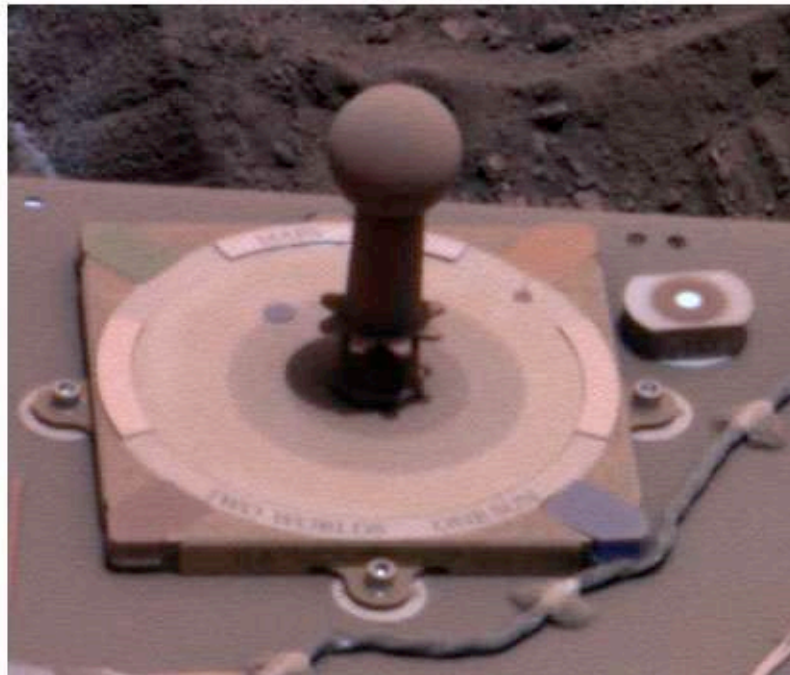
View from Pancam looking back across Spirit's solar array

Opportunity- dust loss from Isc cell noon data



Spirit dust cleaning event-- sol 416

Sol 416A



Sol 417A



Uncalibrated color images

Dust devil in motion



Spirit, Sol 459 (20 seconds between frames)

Close Dust devil



Time
in seconds

Spirit, Sol 456 (20 seconds between frames)

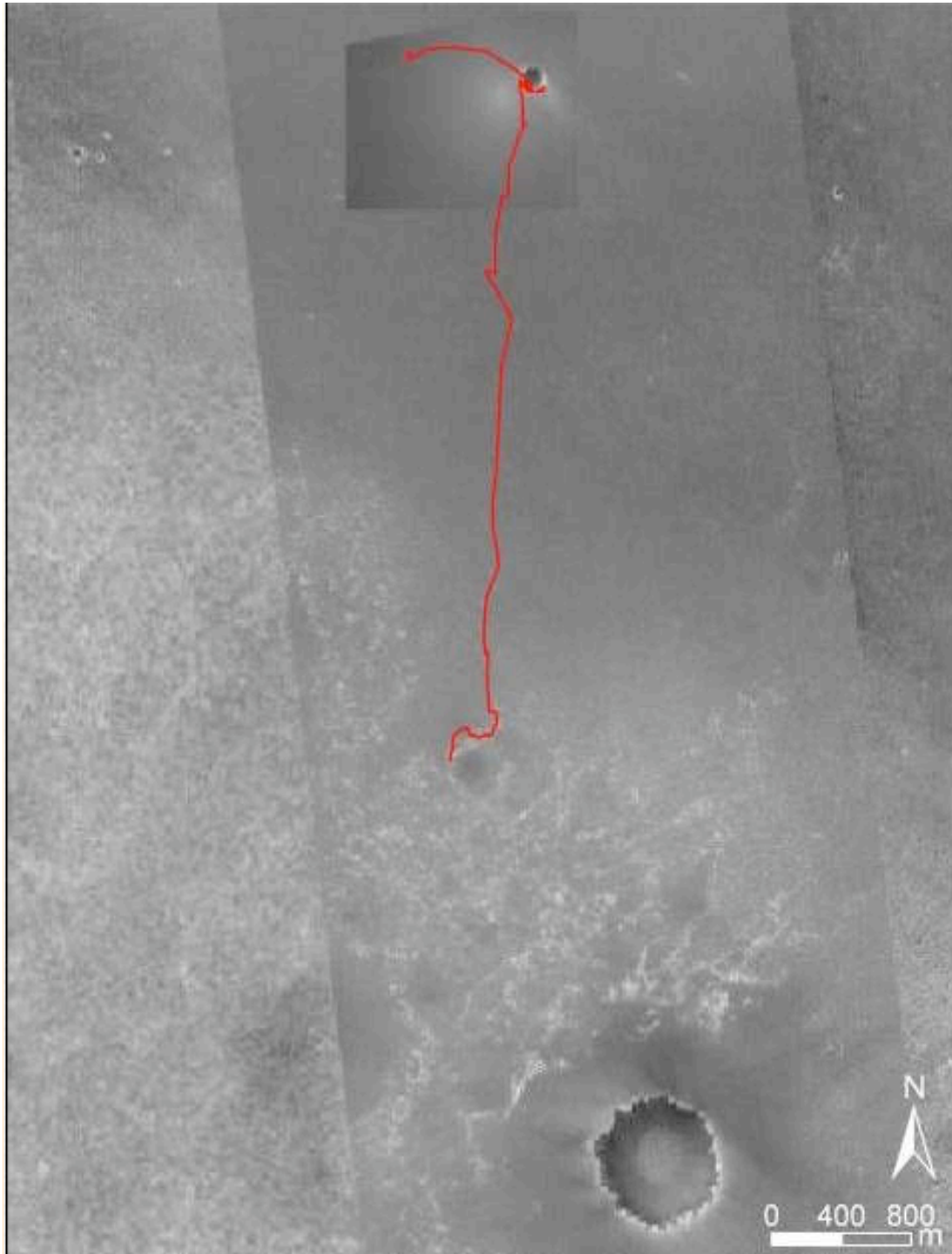
Lots and Lots of Devils!



0000

Sol 568(20 seconds between frames)

Motion enhanced



Traverse toward "Victoria"

Exploration - Landis

Clouds over *Opportunity*



Bitty Cloud, the Movie (B 956)



Earthrise, sol 682

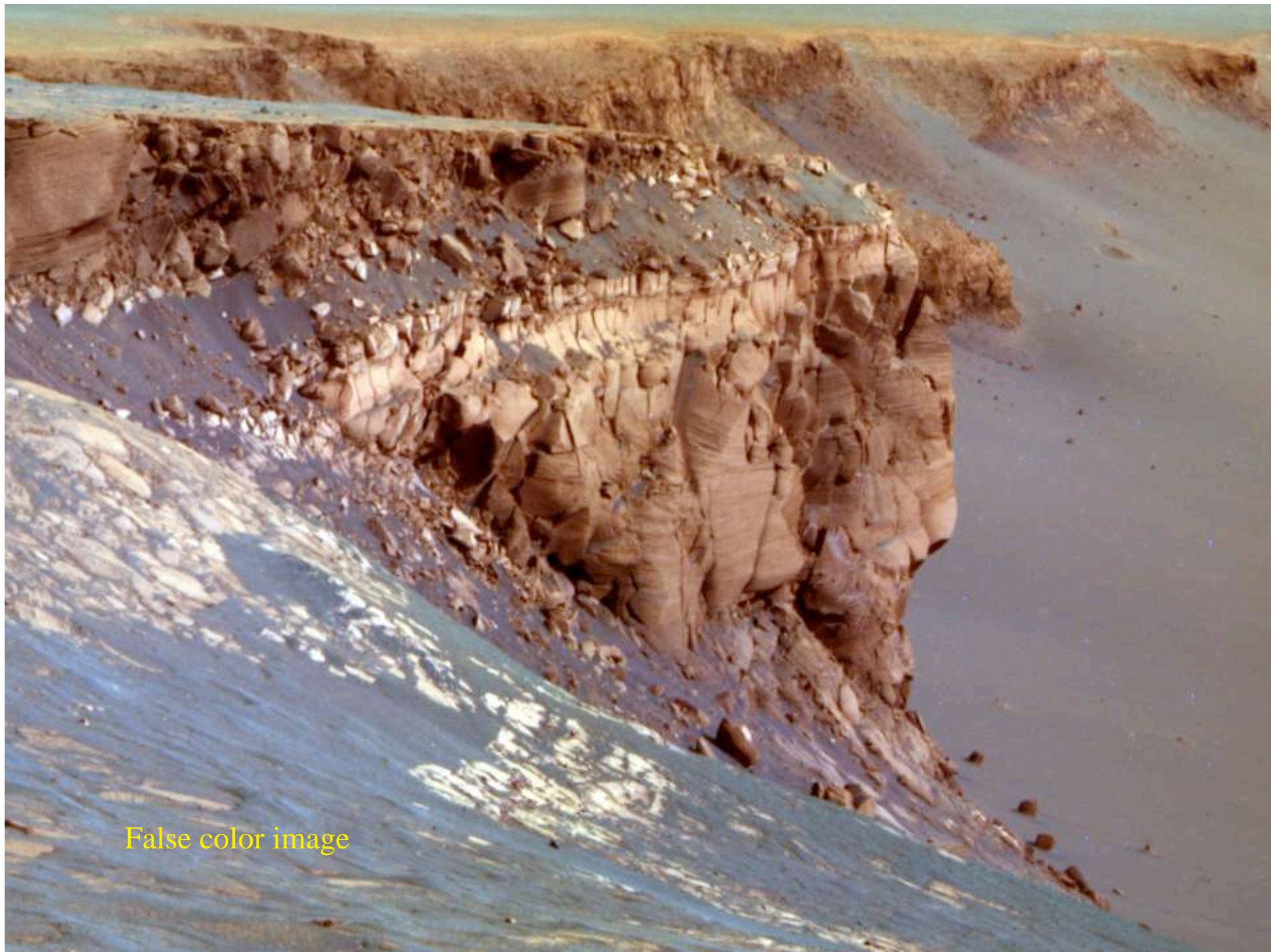


Exploration - Landis



Opportunity Rover viewed from
MRO





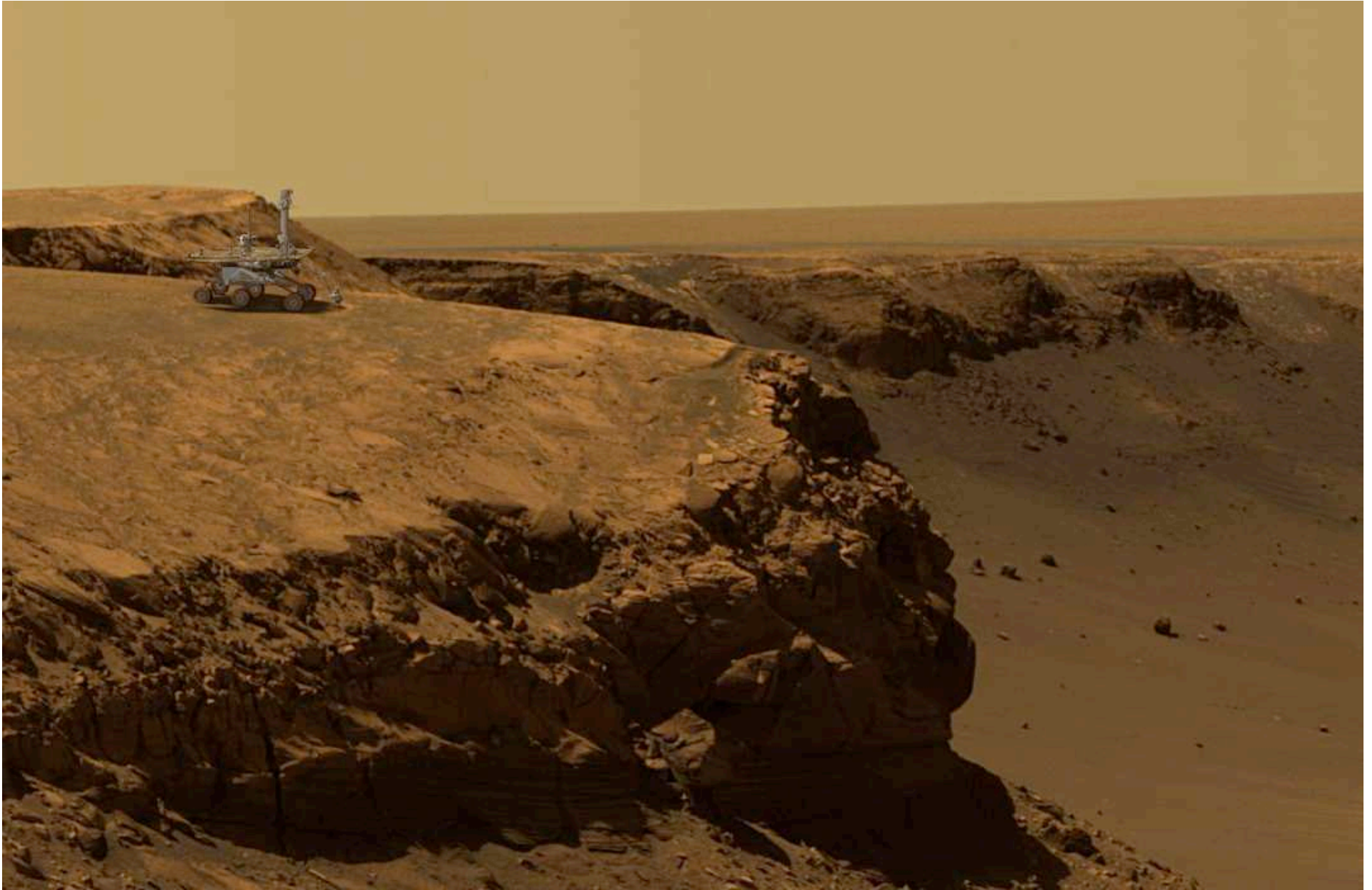
False color image

"Good Hope" close up in
stretched color



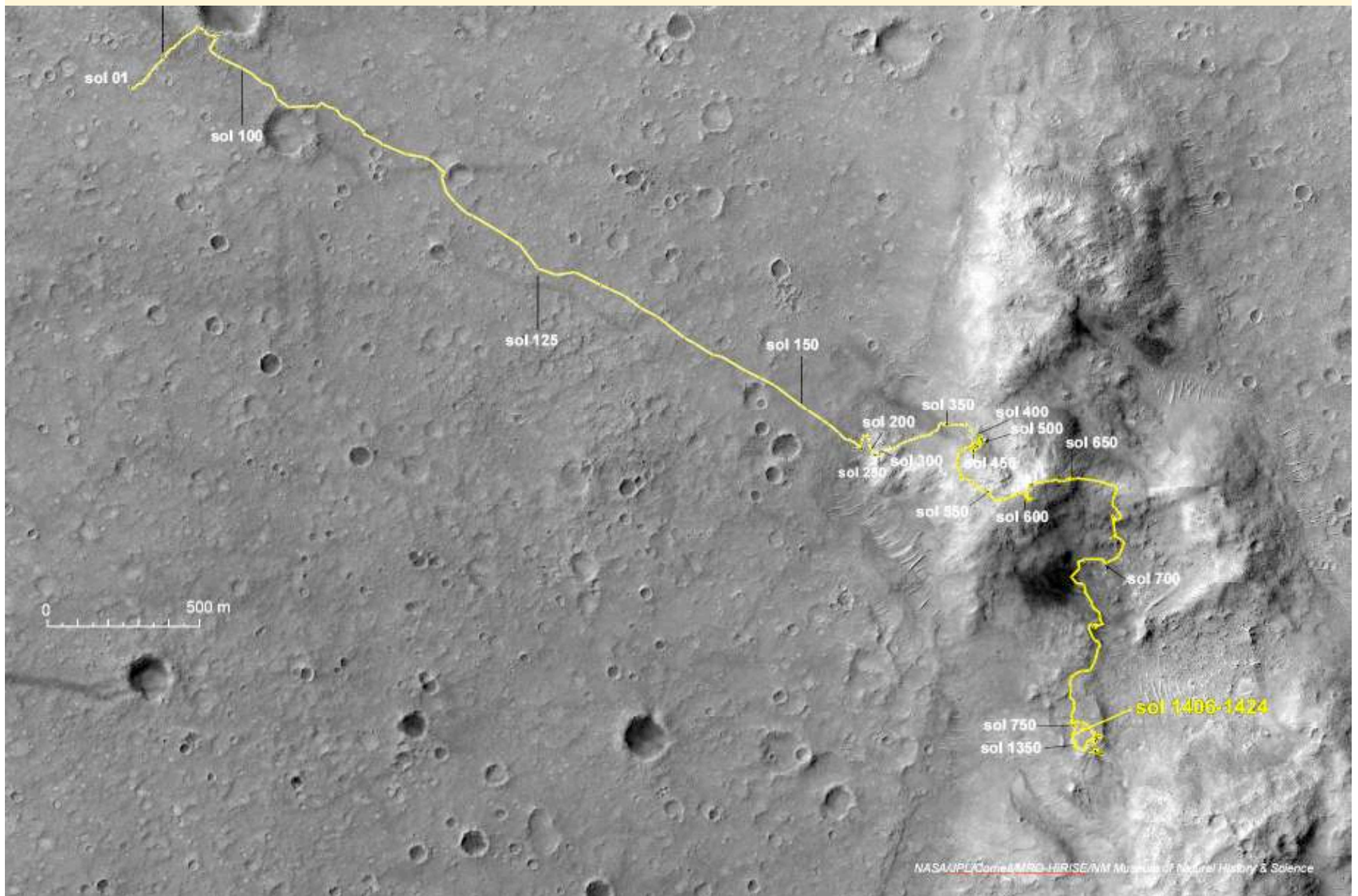


Cabo Corrientes in false color

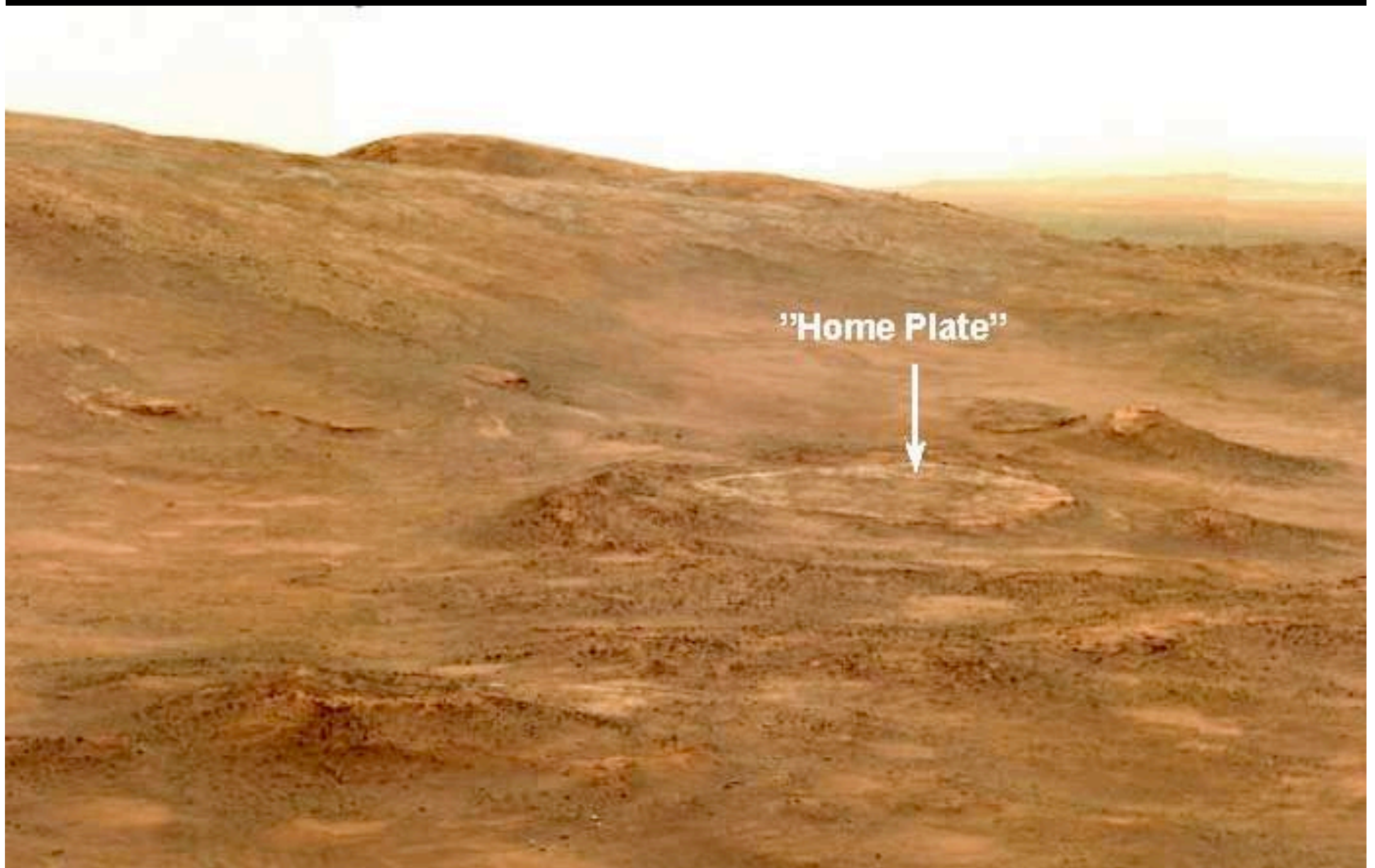


Relative size of Opportunity if it could be viewed at Duck Bay
(pancam true color) **with a little help from Photoshop**
Exploration - Landis

MER A traverse map



Home plate



View from home plate





Home plate
(true color)



Home plate: "bomb sag" (false color)



Skid marks and white salt
under the soil

Spirit Winter haven 2006: Sol 810-811



Spring on Mars:

Dust devil season returns



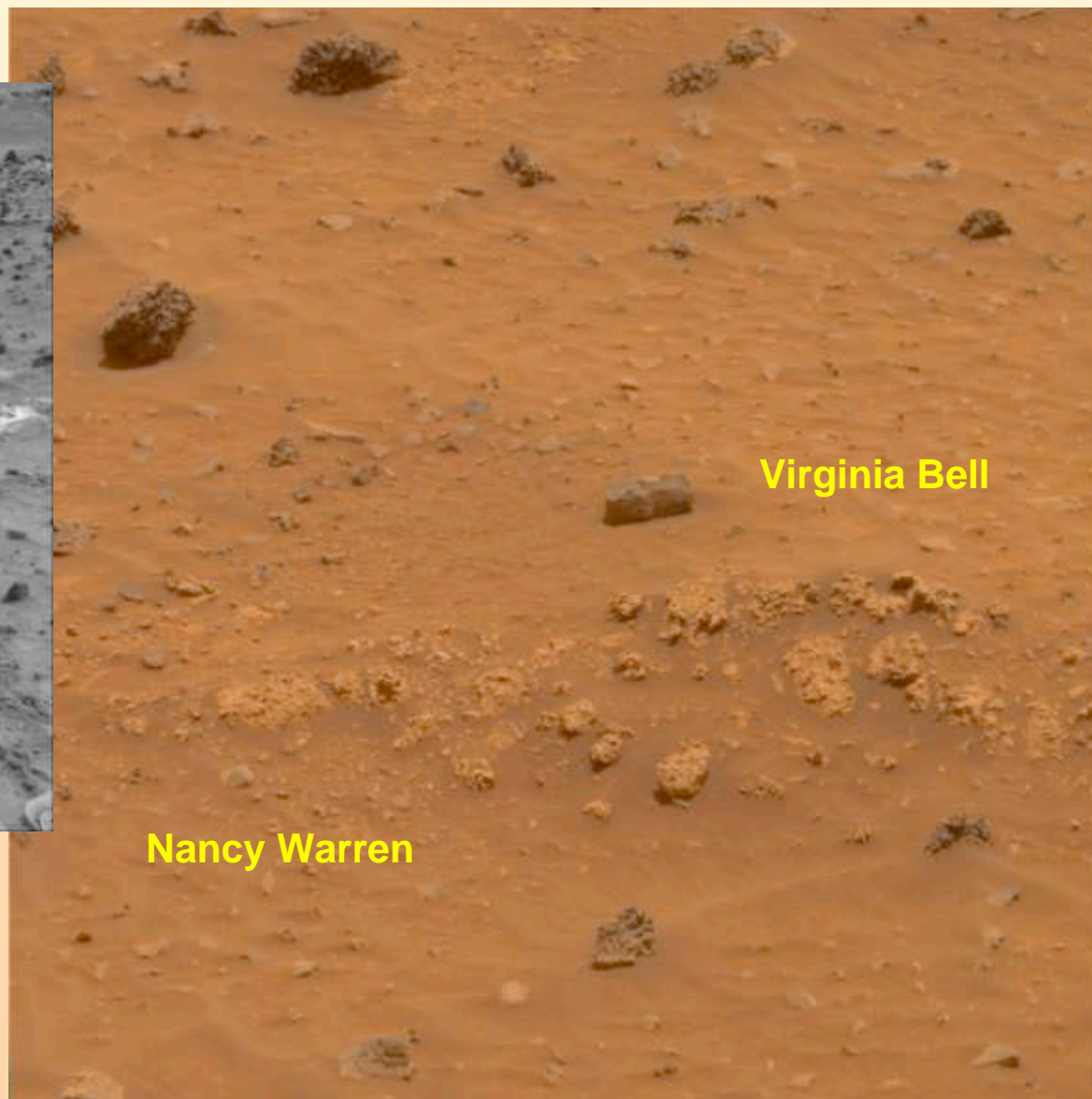
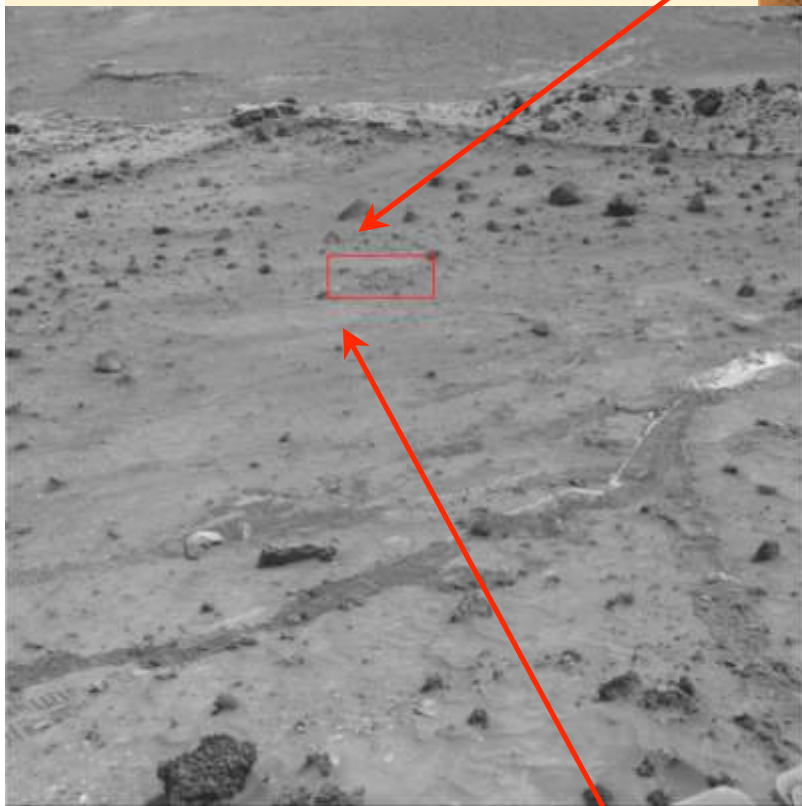
Sol 1120 A

(Motion enhanced)

Exploration - Landis

High Silica Nodular Outcrops

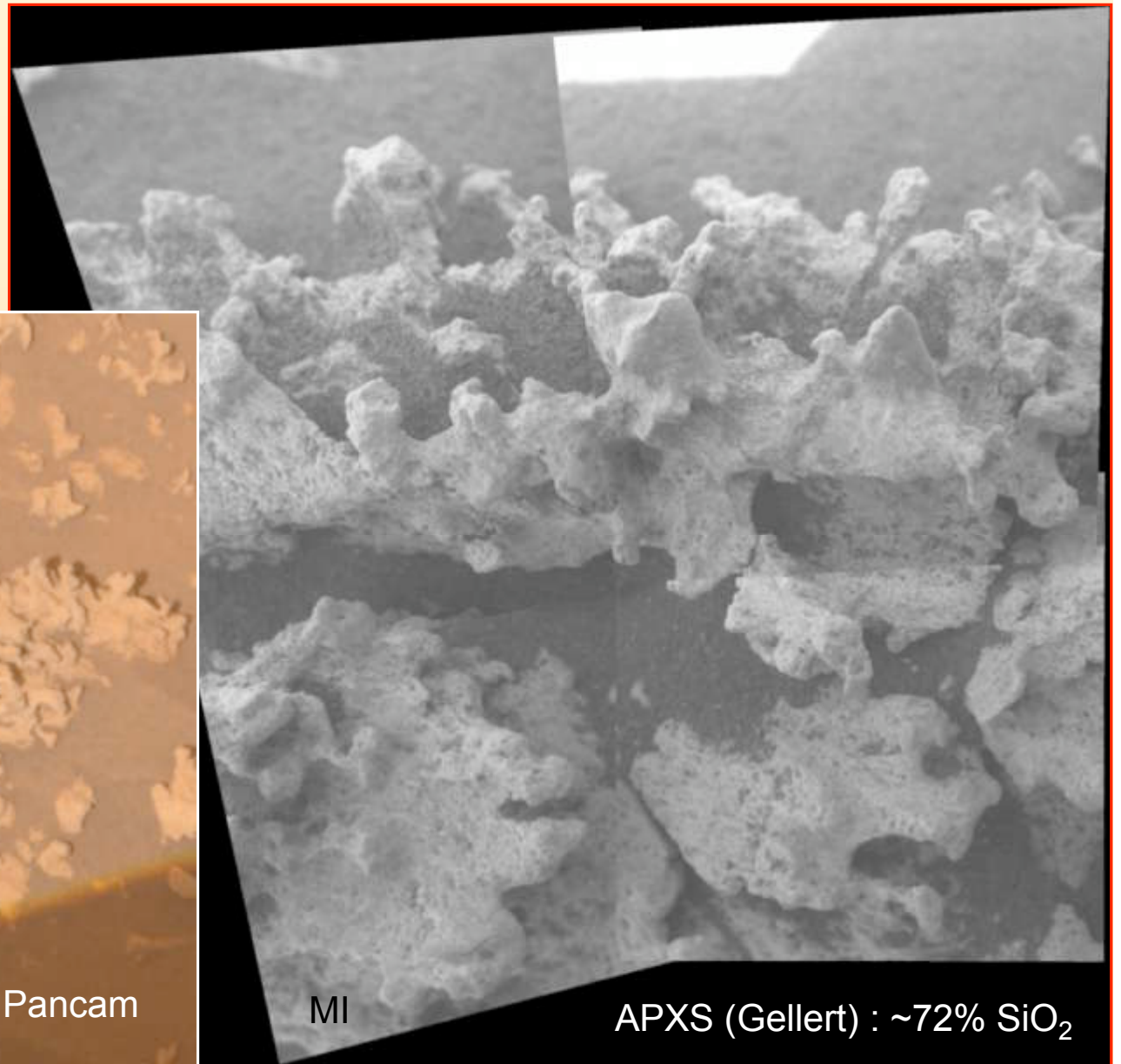
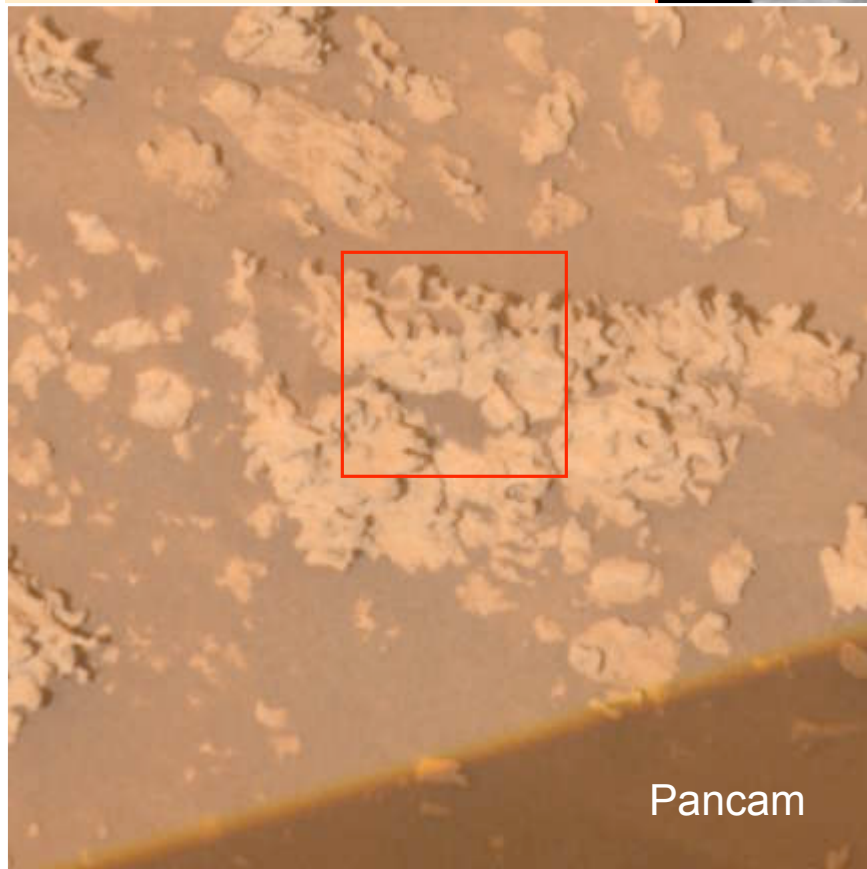
Highest silica percentage found (from APXS):
Soil target "Gertrude Weise": ~90% SiO_2



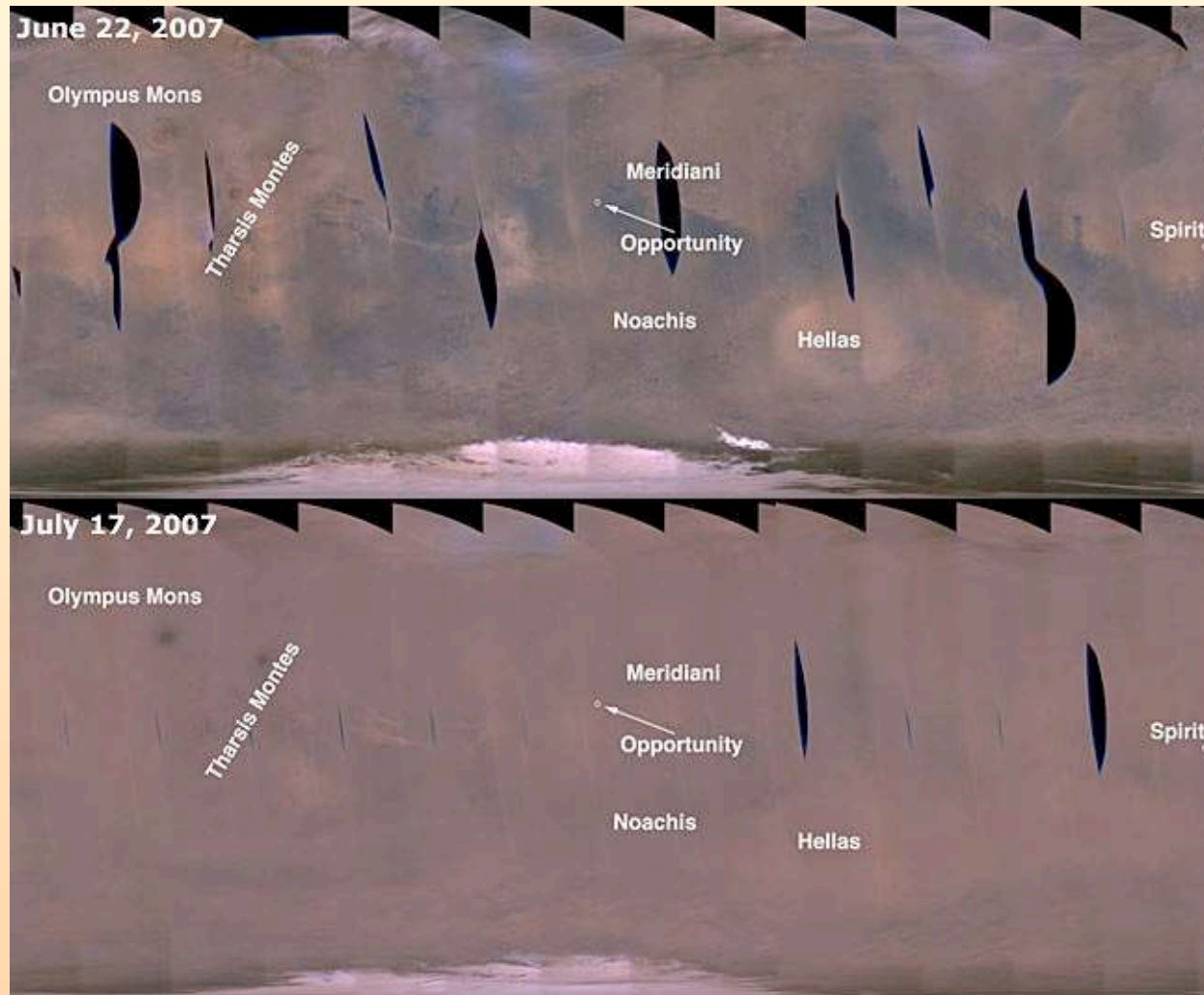
Virginia Bell

Nancy Warren

Silica: Fumerolic alteration?
Signature of hot springs



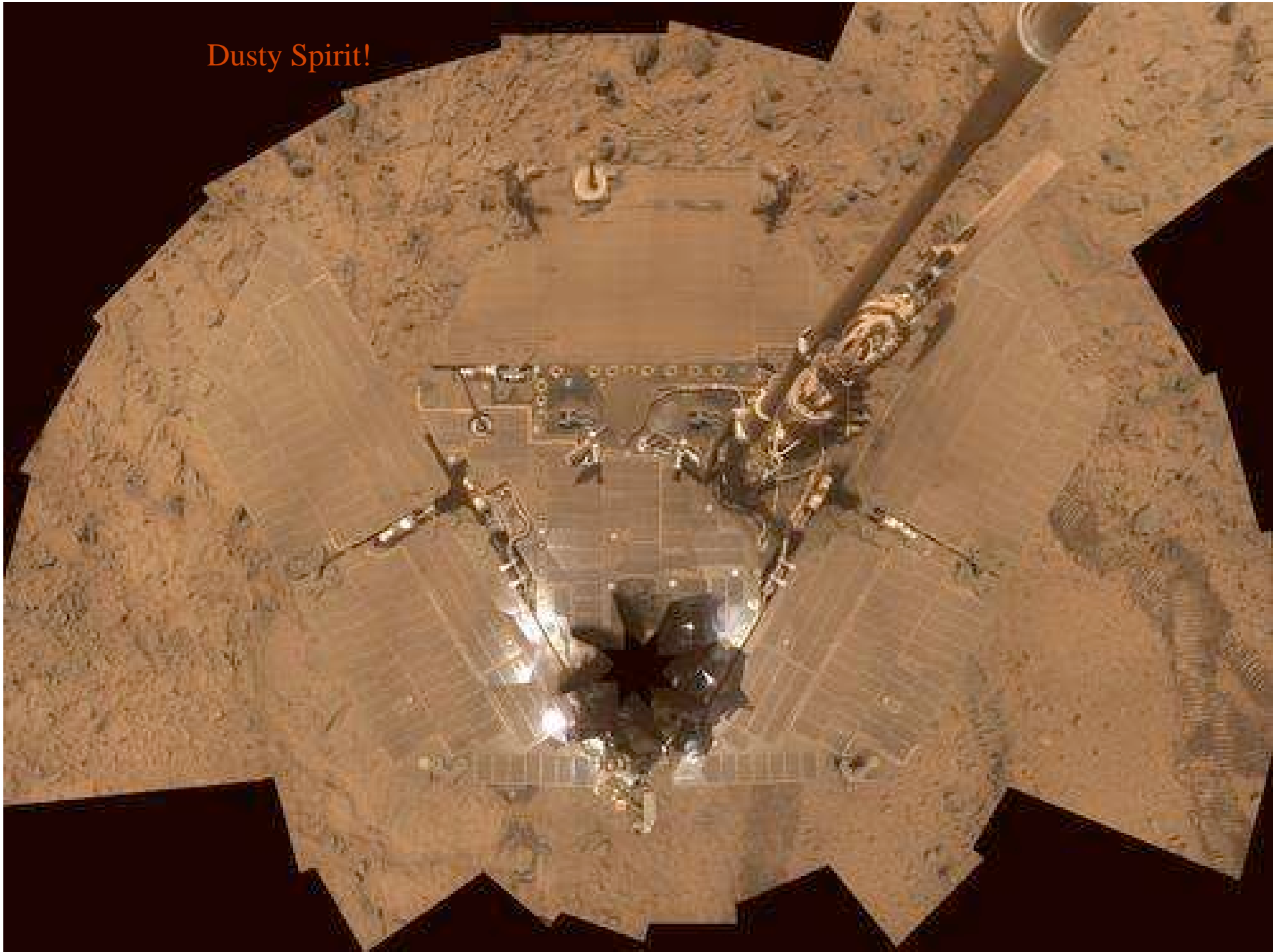
Mars Reconnaissance Orbiter views Dust from Orbit
note loss of surface features due to dust storm!



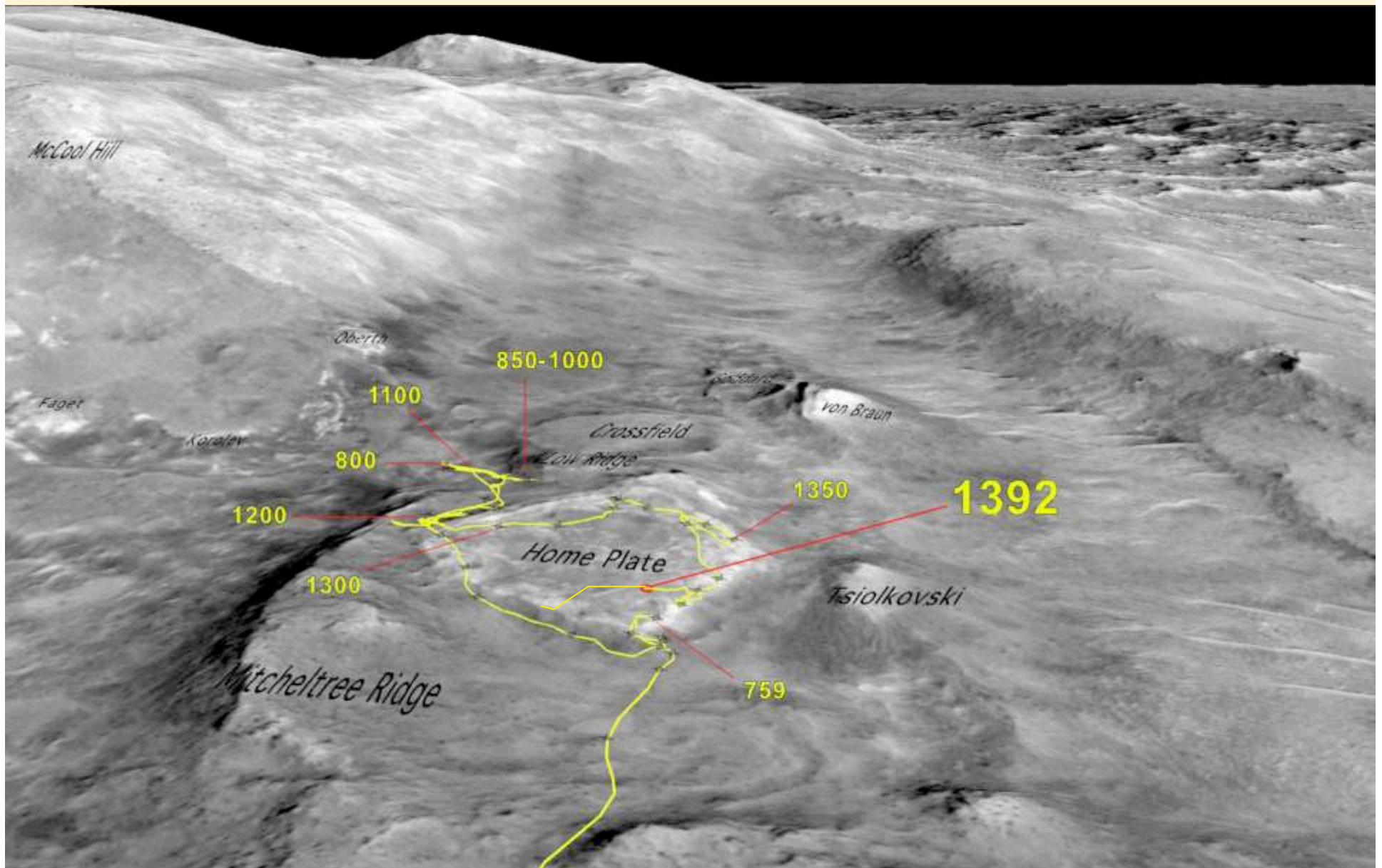
Dust storms



Dusty Spirit!



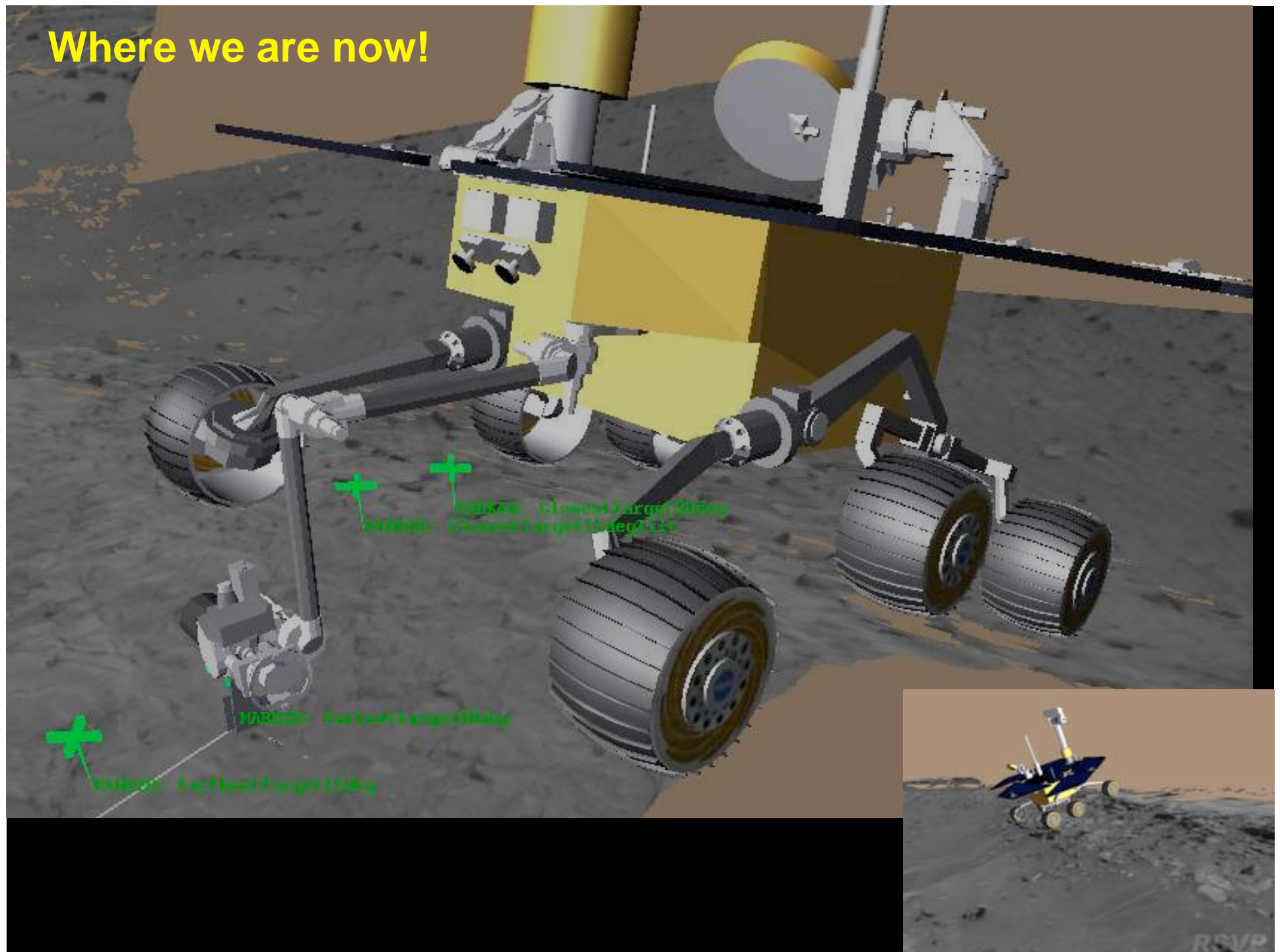
Winter haven at north edge of
home plate



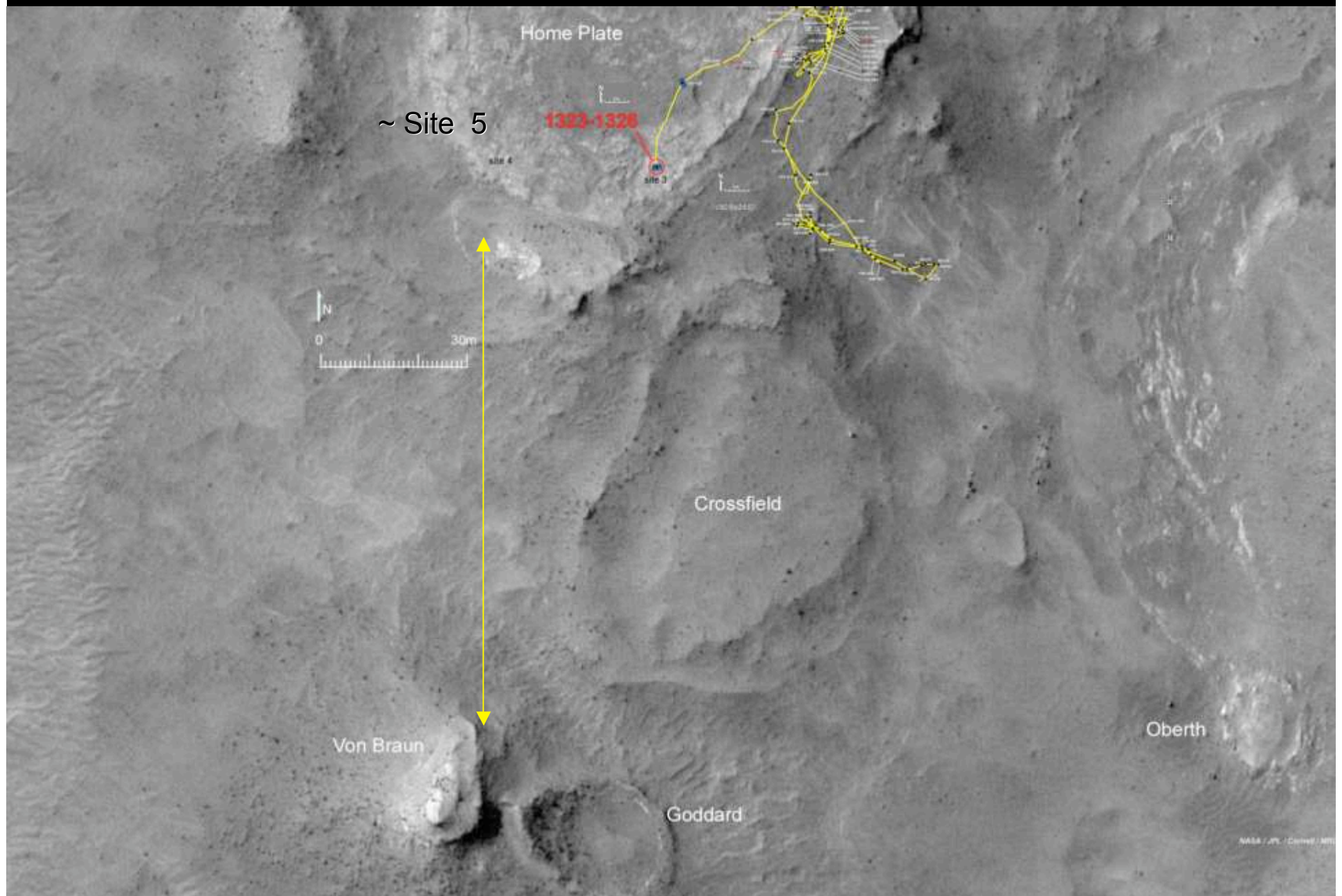
View from our winter haven



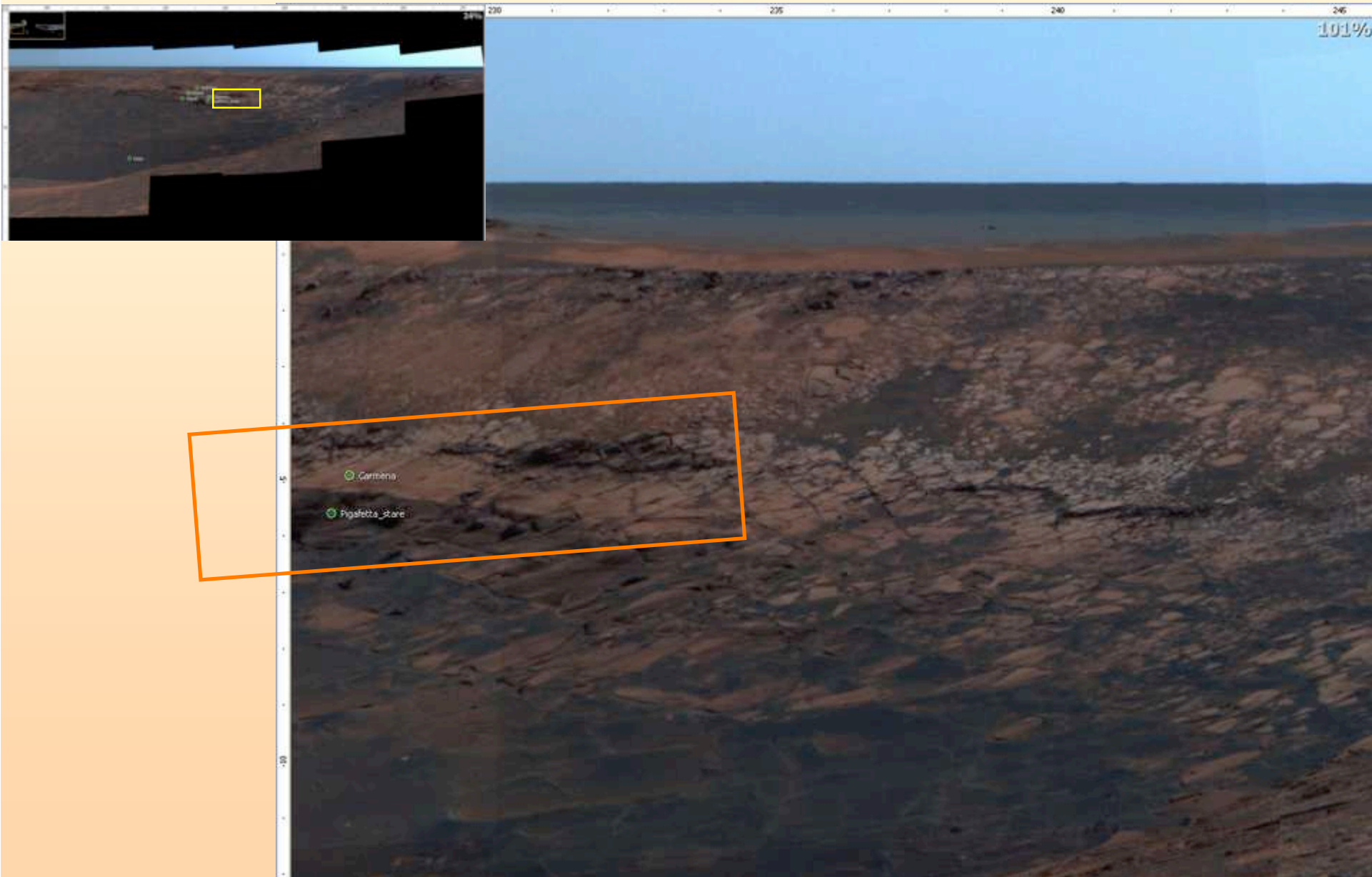
Where we are now!

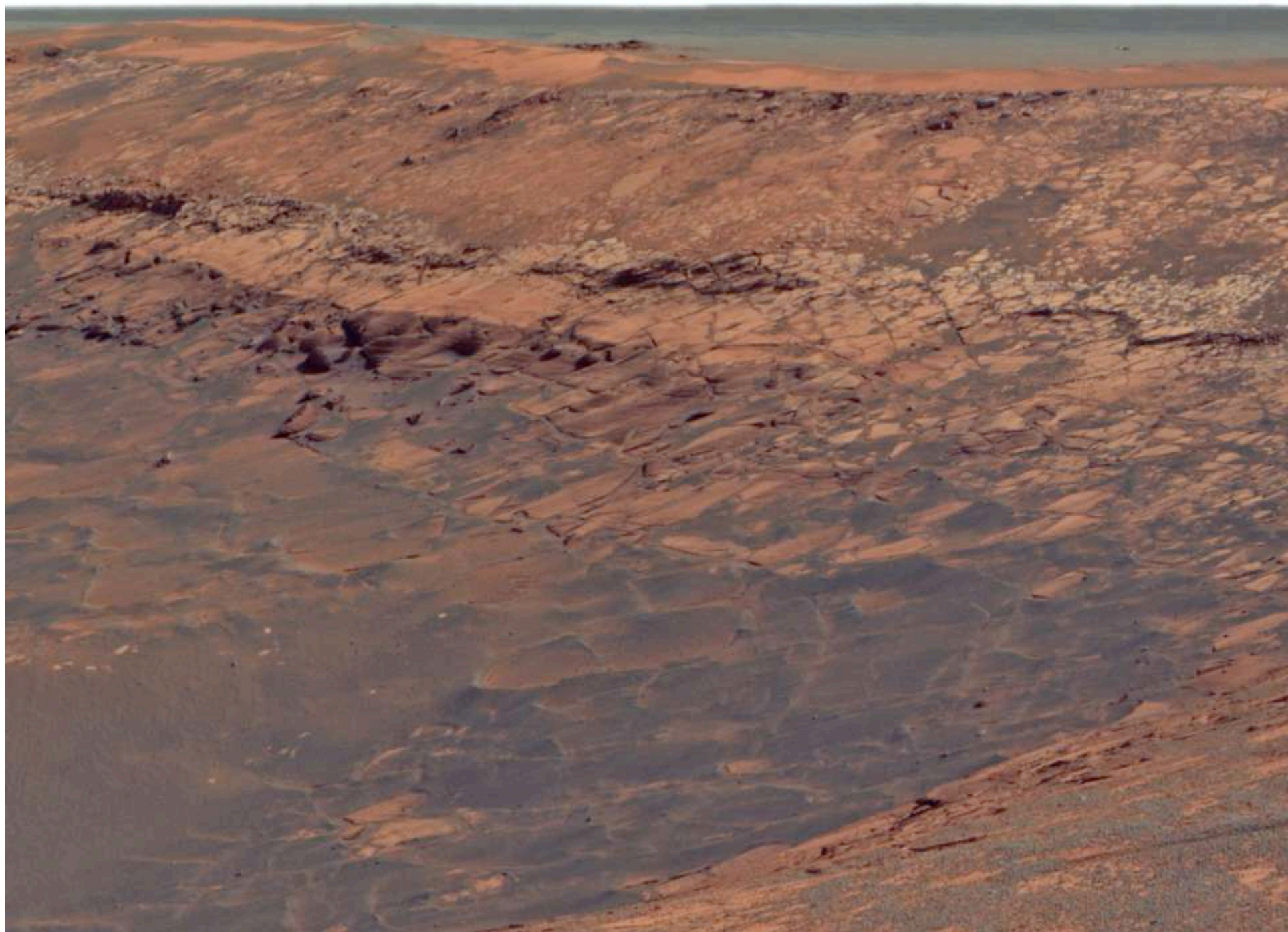


Long term plans: new territory to the south



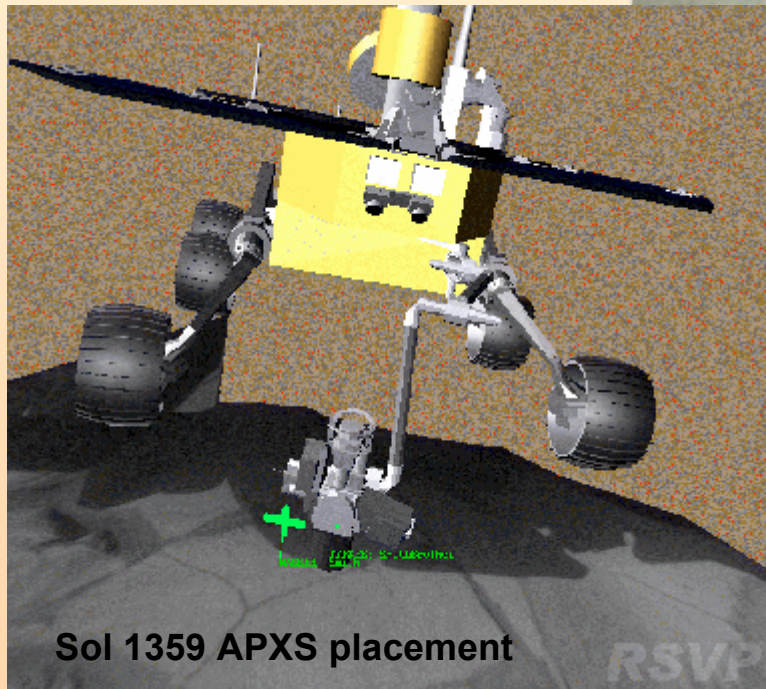
Where we are now: B





Current tasks for MER-B

New target
for RAT
brush/grind



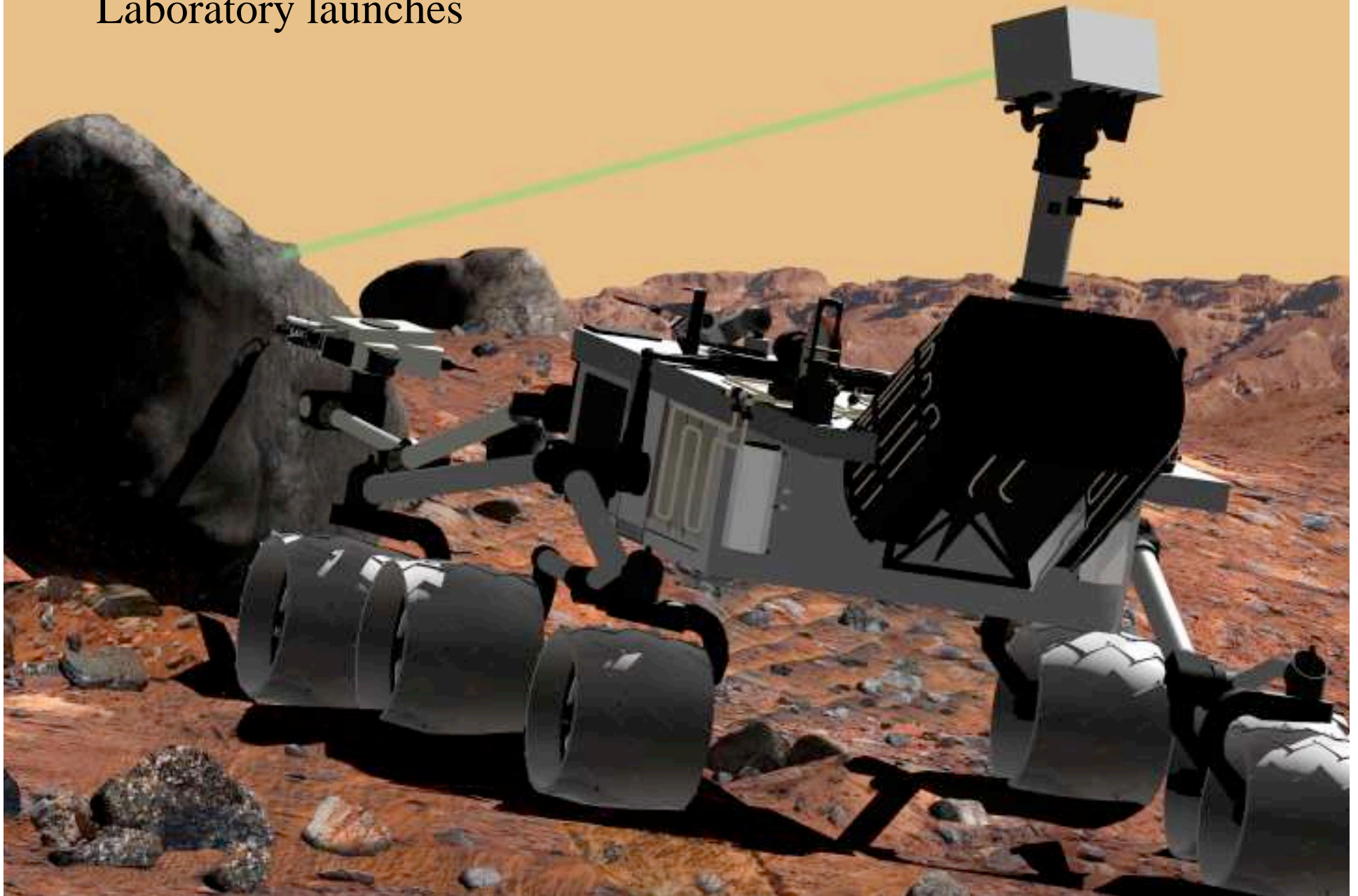
Next landing on Mars: the Phoenix
spacecraft lands, May 25 2008



Phoenix spacecraft



2009: Mars Science
Laboratory launches



Wheel comparisons



MER

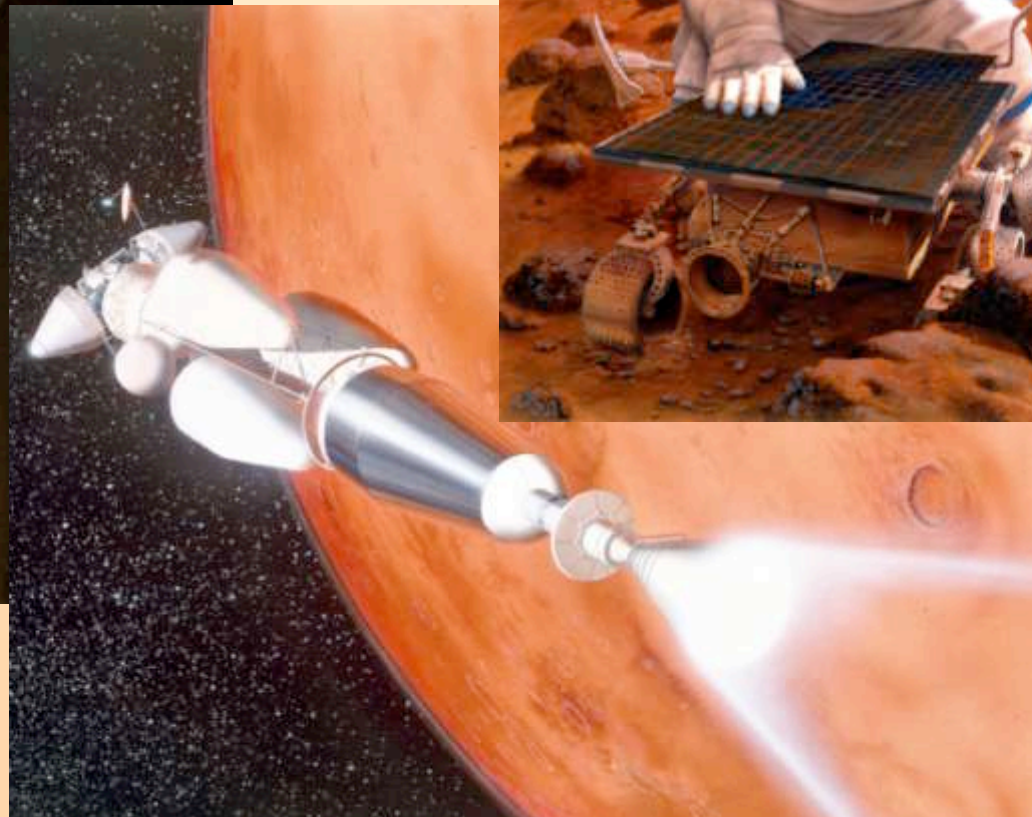
Sojourner

MSL



Future Mars rover?





Launching humans to Mars



Pressurized rover



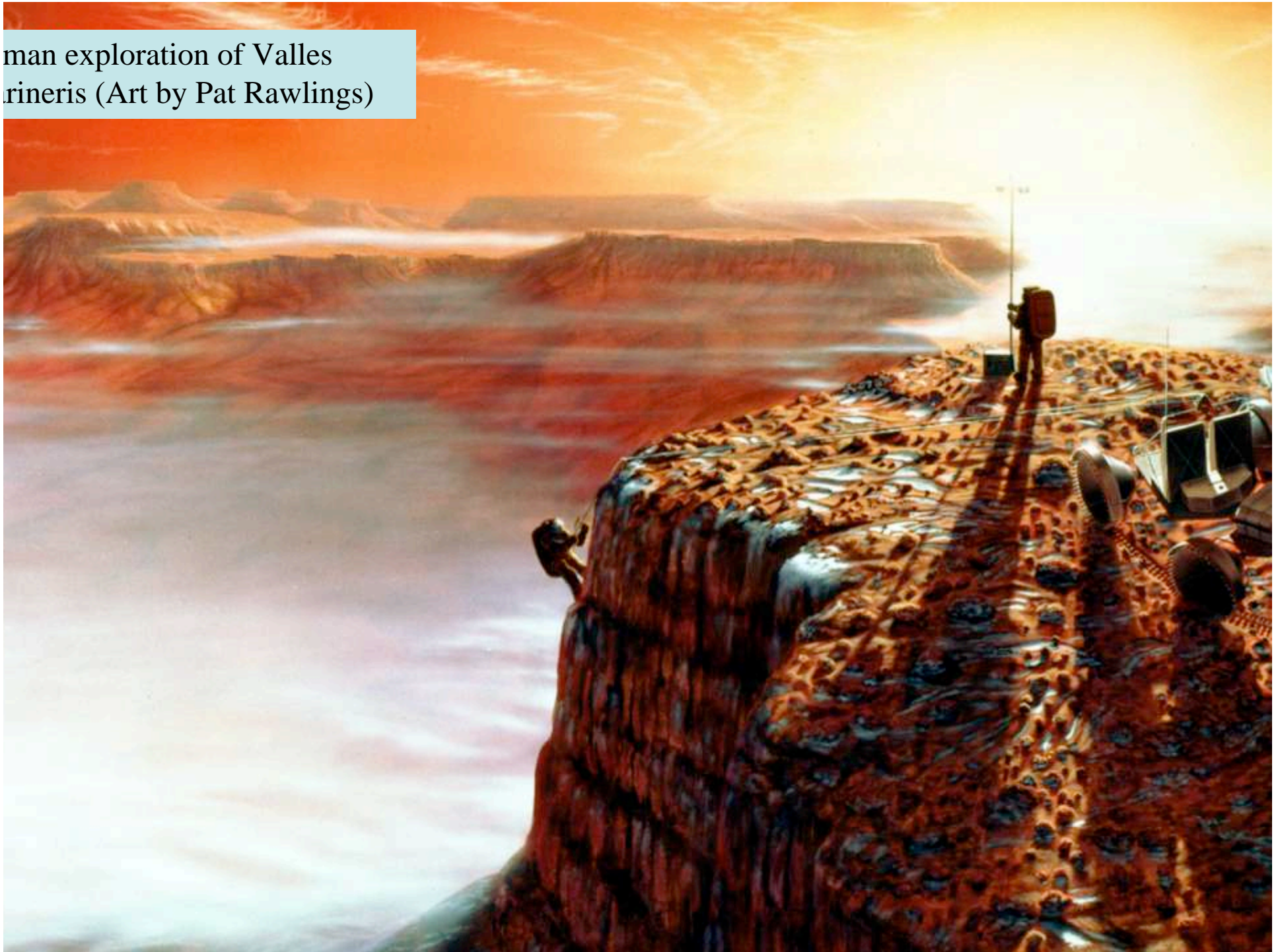
Future Mars habitat

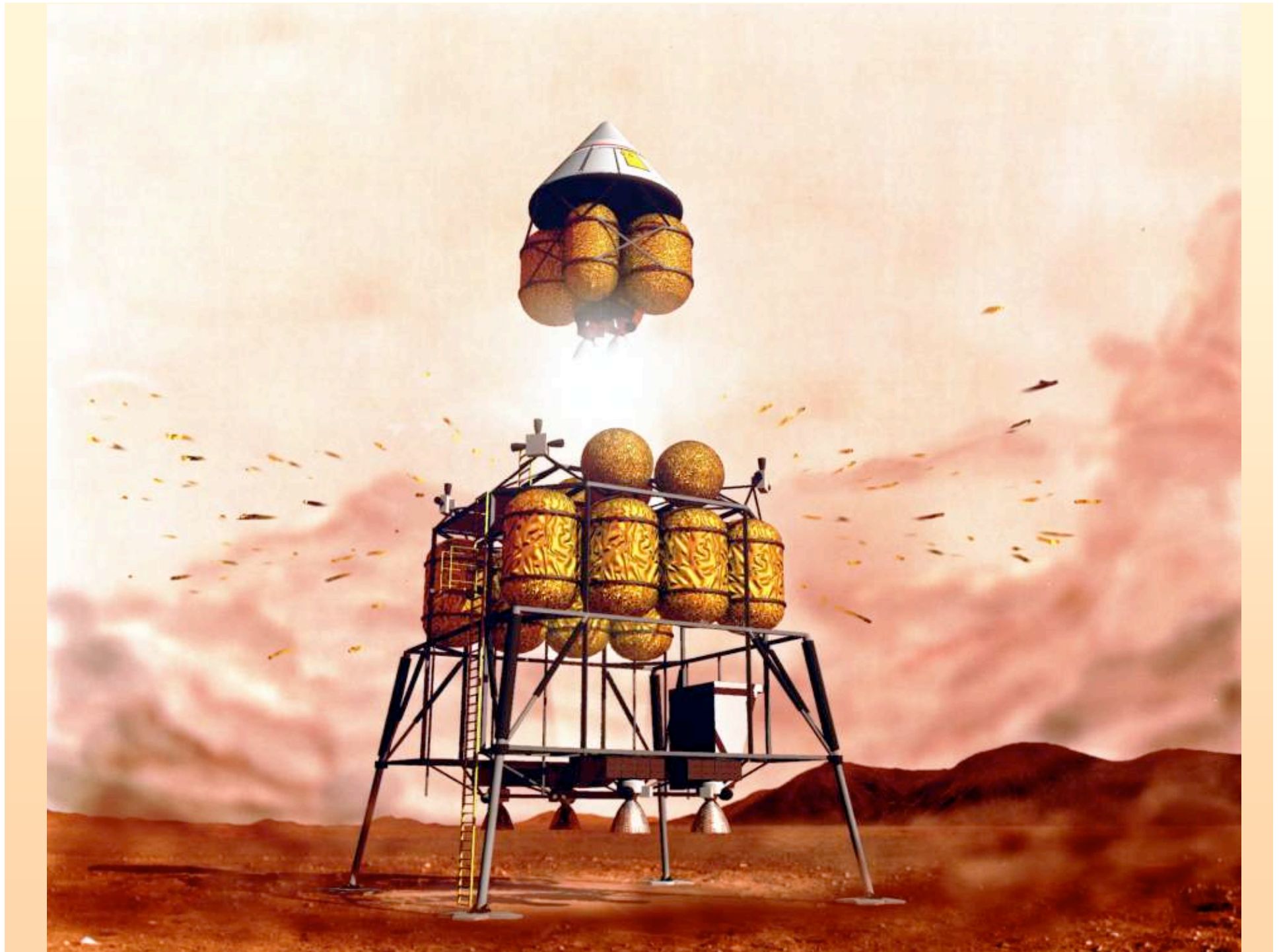


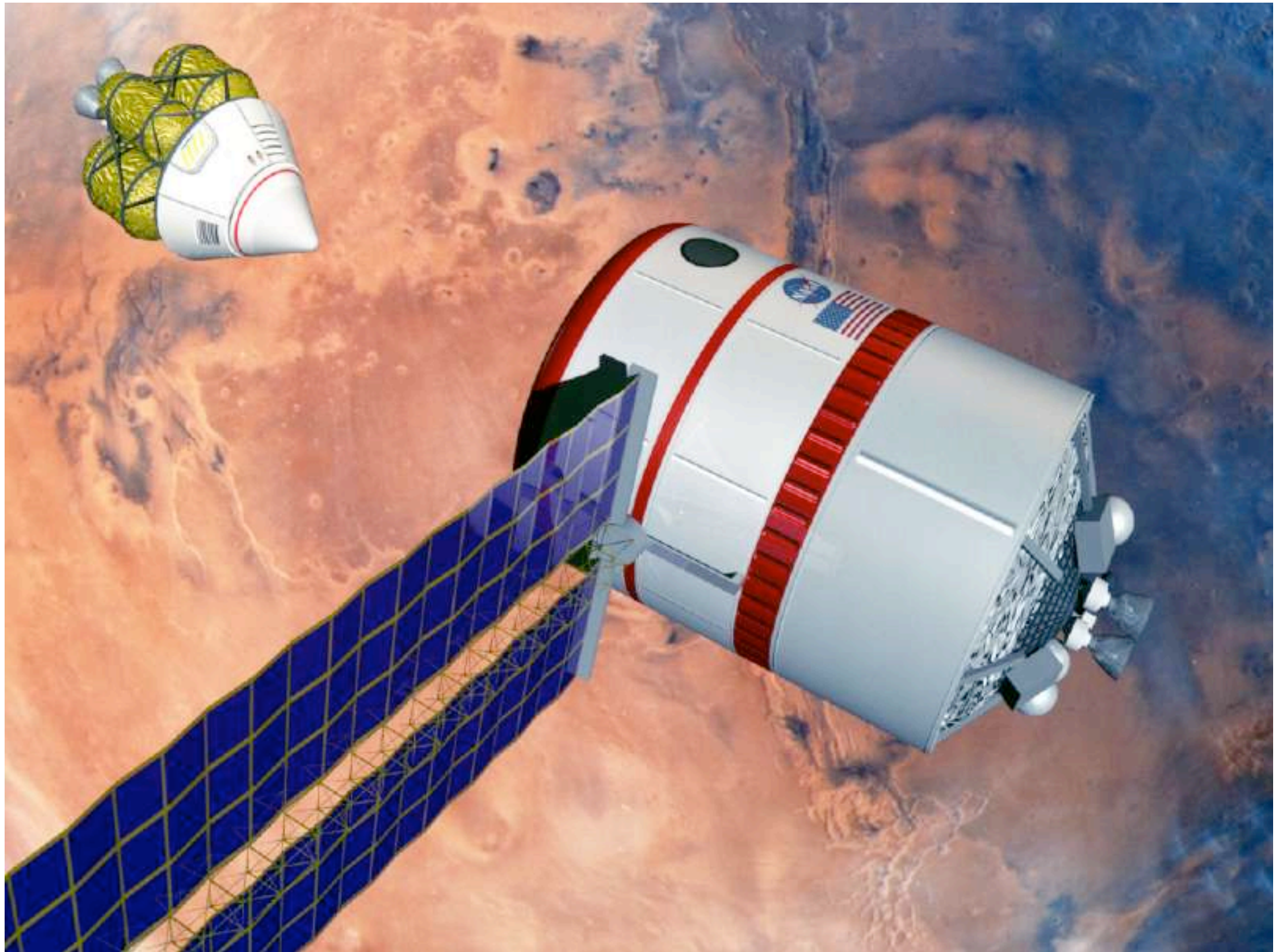
Valles Marineris

Exploration - Landis

Human exploration of Valles
Marineris (Art by Pat Rawlings)







Returning safely to Earth...



Web sites

- Mars Rovers:

- Mars.jpl.nasa.gov



- Planetary Information

- pds.jpl.nasa.gov/planets

